# EFFECT OF A MATERIAL SCIENCE COURSE ON THE PERCEPTIONS AND UNDERSTANDING OF TEACHERS IN ZIMBABWE REGARDING CONTENT AND INSTRUCTIONAL PRACTICE IN DESIGN AND TECHNOLOGY

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# DEDICATION

To the spirit and faith of all the children of Zimbabwe

# ABSTRACT

**Key terms and concepts:** teacher education/training, in-service teacher education/training, design and technology education, technical education, curriculum change and innovation, constructivism, instructional design, instructional/learning strategies, formative and summative evaluations, developmental research.

Historically, technical subjects (e.g. Woodwork) in Zimbabwe have always been taught through the traditional approach, where most teachers have grown accustomed to methods, where they present pupils with problem situations and then proceed to provide solutions to those situations. However, recent developments have led to the consideration of 'Design and Technology' (D&T) as both an approach and a subject. The view of D&T as an approach meant the proliferation of new perspectives relating to instructional practice in technical education. And the intensity of problems associated with differences in perspectives among practitioners has resulted in the quest for continuous change and reform. Many are advocating for the active participation of learners in educational activities. In the Zimbabwean context, the drive for change from the traditional to the more progressive D&T approach has been necessitated by the popularly shared sentiments, expressed during a conference on teacher education in the year 2000 (National Conference on Teacher Education Report, 2000:21) signalling a three-fold challenge in the professional development of technical subject teachers. There is need to increase scientific knowledge in order to approach the teaching of D&T from a scientific perspective, enhance the competence of teachers in solving practical D&T problems through scientific knowledge/principles, and increase the understanding of how to teach pupils to solve technical problems by putting theoretical knowledge into practice. This calls for the design and development of an exemplary course package of instructional materials accommodating these three areas of thrust.

The purpose of this study was therefore to address the following primary research question: 'What effect would a specially designed, developed, implemented and evaluated Material Science (MS) course have on serving teachers in terms of their perceptions and knowledge/understanding regarding content in MS and instructional practice in D&T?' This was then reduced to the following secondary research questions:

- What perceptions of specific aspects of Design and Technology as an approach, do teachers hold?
- What knowledge/understanding of specific concepts in Material Science do teachers hold in relation to the teaching and learning of Design and Technology?
- To what extent are teachers competent to apply the knowledge/understanding gained from the Material Science course in solving practical problems under the Machine Shop Practice course?

Ally's (1997) instructional design model provided the basis for the theoretical framework behind this study. An essential feature of Ally's model, relevant for the study is that, through its well defined developmental stages, it gives a clear sense of direction in the development of instructional materials, going stage by stage.

Culminating in a prototype programme package of instructional materials, the study was approached through 'developmental research' (DR) located in both the quantitative and qualitative paradigms. Quantitative and qualitative methods constituted alternative, not mutually exclusive strategies in handling data according to principles drawn from case/evaluation studies involving questionnaires, interviews, observations and document analysis/evaluation. Participants comprised of 85 teachers qualified to teach Woodwork and Metalwork up to 'O' Level, with the potential to be staff developed for teaching of D&T at ‘A’ Level. The course developed comprised of content in MS and was deliberately designed to influence and promote instructional practice in D&T. A systematic analysis of the curriculum, learners’ needs and specific ideas about teaching/learning helped to inform the design and development of the course.

Findings showed initial *perceptions* of teachers being generally opposed to the principles of D&T, only becoming positive after MS and MSP. The same happened on *knowledge/understanding*, where after starting from a very low ebb, teachers later became more knowledgeable and confident. They also performed reasonably well during the final MS examination with an average mark of 65%, inclusive of coursework where the highest mark was 80% while the lowest was 53%. *Application of MS under MSP* was demonstrated at various levels as teachers were observed working in workshops. Data from interviews also helped to confirm claims by teachers regarding their application of MS. More evidence of teachers applying their theoretical and practical knowledge in problem-solving was found in design folios.

It is concluded that the initial perceptions of teachers that negate major principles of D&T were typical of their strong roots in the traditional approach to the teaching and learning of technical subjects experienced during their initial teacher training. The low level understanding of concepts in MS before the course was evidence of a weak physical science background realised during initial teacher training. However, the positive perceptions and higher levels of knowledge/understanding on identified concepts after the MS course were an indication of the impact the course had had on the professional development of these teachers. Conclusions drawn in this study had several implications for; the relationship between MS and MSP within D&T, learner involvement in relation to the effectiveness of instructional materials, the professional development of teachers and developmental research in relation to instructional design. Findings of the study contribute to knowledge on issues relating to the design, development and implementation of courses in D&T.



Although observations were made during MSP to check on whether or not teachers used their knowledge of MS to solve practical problems, the time (60 hours) was not enough to meet the demands of the course. Perhaps, it would have been helpful to observe them for longer periods in their normal working environments within schools. Tracer studies aimed at systematically observing teachers in action over at least a year would be helpful. It is hoped, this would yield a more realistic picture regarding the impact of teaching on the perceptions and knowledge/understanding of pupils in various contexts. Further research is also recommended on the following: whether or not teachers’ perceptions of the D&T approach and knowledge/understanding of concepts in MS are influenced by factors such as experience and age; if the instructional package used in this study could be adapted for application in other spheres (areas apart from MS and levels apart from the B.Ed. degree); if the concept of ‘teacher researcher’ could be tried with the teachers at their respective schools; the extent to which one could balance issues about learning MS, learning about MS and doing MS. and explore the possibility of teachers involving their pupils/student in the design and development of their courses.

# DECLARATION

I, **Peter Kwaira**, hereby declare that this study, 'Effect of a Material Science course on the perceptions and understanding of teachers in Zimbabwe regarding content and instructional practice in Design and Technology,' is my own creation which has not been submitted for any degree or examination in any other university. All the sources that I have used or quoted have been appropriately indicated and acknowledged by means of complete references.

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**Peter Kwaira**, November 2007 (University of the Western Cape)

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# ABBREVIATIONS

**BBC**: British Broadcasting Corporation

**B.Ed**.: Bachelor of Education

**BLD**: Building

**B.T.T.C**.: Belvedere Technical Teachers' College

**C.I.E**.: Cambridge International Examinations

**C.T.T.C**.: Chinhoyi Technical Teachers' College

**D&T**: Design and Technology

**D&T. Ed.**: Design and Technology Education

**DTEMOD**: Design and Technology Education Module

**DR**: Developmental Research

**DRA**: Developmental Research Approach

**G.T.C.**: Gweru Teachers' College

**HE**: Home Economics

**MS**: Material Science

**MSP**: Machine Shop Practice

**MW**: Metalwork

**NCETE**: National Commission for Excellence in Teacher Education

**NCTER**: National Conference on Teacher Education Report

**OECD**: Organization for Economic Co-Operation and Development

**STES**: Science-Technology-Environment-Society

**UNESCO**: United Nations Educational Scientific and Cultural Organisation

**UNICEF**: United Nations Children's Education Fund

**UZ**: University of Zimbabwe

**WOCATE**: World Council of Associations for Technology Education

**WW**: Woodwork

**ZIMSEC**: Zimbabwe Schools Examination Council

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# Chapter 1
# BACKGROUND AND STATEMENT OF THE PROBLEM

This chapter introduces the whole study by focusing on the research questions and putting them into context within the relevant conceptual framework developed for this study.

## 1.1 INTRODUCTION

Curricula the world over are changing rapidly, and in Zimbabwe as elsewhere, there is need to relate teacher education and training to the prevailing politico-socio-economic demands of the curriculum, which now includes 'Design and Technology' (D&T) within the context of Technical Education. In recent years, technical subjects have made spectacular advances and the societies in which we live, work, and learn have undergone some dramatic changes (Keeves & Aikenhead, 1995).



During a national conference on the theme, 'Teacher Education for the 21st Century: Issues and strategies' in the year 2000, the then permanent secretary for the Ministry of Higher and Tertiary Education in Zimbabwe expressed the need for developing a teacher education system responsive to the prevailing social, political and economic changes within Zimbabwe [National Conference on Teacher Education Report [(NCTER), 2000:1]. This reinforced the speech by the then Minister of Higher Education and Technology, when he officially opened the conference. He expressed the need for continued renewal and review of teacher education and training. Delegates were challenged to address the issue of quality, particularly in teacher education and higher education in general ahead of the new socio-politico-economic era of an emerging millennium. The need for a paradigm shift was also emphasised regarding focus on quality of the teaching force as opposed to mere quantity (National Conference on Teacher Education Report, 2000:1).

Historically, technical subjects in Zimbabwe (e.g. Woodwork and Metalwork), have been taught through the traditional approach where teachers would present pupils with problem situations and then proceed to provide solutions to those situations. A good example could be that of a teacher asking pupils to make a tea-pot stand for their mothers and then proceeding to stipulate the material(s), measurements, and the type(s) of joint(s) required to join the various components together (Kwaira, 1998). Pupils would then be required to simply follow instructions relating to laid down procedures. The teacher would give knowledge and the learner would be the recipient expected to retrieve relevant bits and pieces of information as required, especially in examinations. It is such a 'banking concept' of education that Freire (1972) has critiqued in his thesis; 'Pedagogy of the Oppressed'. In 'The Politics of Education, Culture, Power and Liberation', he (Freire, 1985) has maintained his criticism of the metaphor of education as 'banking', elaborately equating the business of education under this metaphor to the act of deposition in which students become the depositories while the teacher is the depositor. Paulo Freire describes how people of conscience can move through different stages to ultimately be able to take action and overcome oppression (Ornstein & Hunkins, 1988; Ornstein & Hunkins, 1993). To effect major change, at what he calls the 'critical transformation stage', people must become active participants in changing their own status through social action aimed at the larger social order. Here Freire's (1972) views of 'critical constructivism' are in agreement with those of Vygotsky (1986); Kincheloe (1991); Cobern (1996); Duschl and Hamilton (1998); Lauzon (1999); Terwel (1999); Colburn (2000); Chak (2001); McCaslin and Hickey (2001); Meachum (2001); Donald, Lazarus and Lolwana (2002) in their deliberations on 'social constructivism'.

Freire (1985 & 1990) also advocates for a dialogue or match between students and teachers, and for sensitivity to change. Even from a much earlier debate, Freire (1970) refers to what he terms a curriculum of 'Human phenomenon – Problematic situations – and Background awareness', which he claims has the potential to transform the world. Accordingly, the curriculum focuses on community, national, and world problems; and has to be based on core or inter-disciplinary approaches. McNeil (1990); Young (1990); Seigfried (1996); Pinar (1999) and Marsh and Willis (2003), being reconceptualists and critical theorists, see the thrust of such a curriculum being the development of individual self-actualization and freedom through cognitive and intellectual activities, which would in turn liberate people from the restrictions, limitations and negative controls of society. These theorists appear to be primarily concerned about people, about the curriculum experience rather than the curriculum planned. They hold that educators must shift their attention from curriculum development to curriculum understanding. This indicates a progressive shift from knowledge to activity or from theory to practice and from reflections to actions in a situation where the curriculum attempts to create new conditions and environments that improve the human condition and the institutions of society (Ornstein & Hunkins, 1998; Ornstein & Hunkins, 2004). This implies that practice and activity become more meaningful when guided and informed by knowledge and theory, thereby suggesting a close relationship between these factors. One can draw parallels between Paulo Freire's ideas and the main ideals founded in D&T, especially on the issue of translating theoretical knowledge into practical activities. 'Parallels and relationships' in this case do not imply Freire's (1972) ideas and the ideals of D&T being exactly the same! The key word is 'similarity', where if one was to argue for, and agree with the fact that Paulo Freire, in his thesis 'Pedagogy of the Oppressed' puts forward a proposition to promote 'Education for Liberation' (liberation of the mind in terms of independent thinking and decision making); s/he would find traits of such an education in D&T. In this regard, Freire's ideas closely relate to the ideals of D&T when the practitioner or problem-solver (e.g. student) is expected to make independent decisions during a problem solving task. According to Gagne (1987), problem-solving involves one being creative in combining established and known rules or principles into new elements to solve a given problem. The main argument appears to be a call for an education that empowers learners to play an active role on matters to do with their lives and/or welfare. Melnick (2002) has advanced a similar line of thought during his discussion of the roles of virtual schools, given the changing face of education with the advent of the 21$^{st}$ century:

> Virtual schools should hold out the possibility of the global classroom, democratization of knowledge, student–driven learning, and robust, authentic curriculum that is constantly being improved upon by each successive group of learners (Melnick, 2002:85).

In this study, a decision was made to have teachers, who happened to be the learners in this case, actively and intimately involved in the design, development and evaluation of the intended package of instructional materials from the beginning, right up to the end. Ingram (1994) applied this approach with a group Technology teachers she was working with in the development of a model curriculum.

In agreement with the line of thinking held by critical theorists are postmodernists like: Giroux, Lankshear, McLaren and Peters (1996); Doll (1993); Slattery (1995); Peters (1995); Jencks (1992) and Neville (1992) who hold the view that there is not one way to interpret or theorize about the curriculum. Post modernists are constructivistic in persuasion since they define the world as emergent, fluid, chaotic, open, interactive and ongoing (Harvey, 1992). This background implies their main stance/orientation being contrary to the modernist view that there is indeed a master/grand narrative for anything. According to Gagnier (1990) post-modernists challenge and question the grand claims proclaimed by modernists about key concepts such as justice, validity, reliability and truth; and likewise, query the rigidity sometimes suggested by related concepts like the curriculum, instruction, pedagogy, education, schooling, student and the teacher. This point is elaborated on later in Chapter 2.



Recent developments in Zimbabwe have culminated in the concept of D&T being adopted both as an approach and as a subject. The approach option has dominated the lower levels of the secondary school system (forms One to Four) since 1987, while the subject option has meant the merging of various technical subjects into one subject (Design and Technology) at 'A' Level. The subject option has been more recent, commencing with workshops and seminars on syllabus development in 1996. It is however interesting to note that although as an approach, the concept has already had an influence on the curriculum, having the concept of D&T as a subject at 'A' Level has not met with the same success. Despite debate on syllabus development at national level dating as far back as 1996 (to which the Department of Technical Education of the University of Zimbabwe was invited by the Ministry of Education and Culture on several occasions), the subject has remained on the shelf. Even the latest 'A' Level syllabus (2002 version) developed by the Zimbabwe School Examination Council (ZIMSEC) in collaboration with the Cambridge International Examinations (CIE) has met with the same fate. This has been suspected to be due to the lack of qualified teachers to teach the subject at ‘A’ Level (NCTER), 2000:1].

A common criticism of D&T in the Zimbabwean curriculum today has been the fact that it does not play an integral role in the instructional process (NCTER, 2000). Apart from failing to teach the subjects at ‘A’ Level, teachers appear to use D&T as an approach on a very limited scale. While several factors seem to have contributed to this problem, teacher education has appeared to be at the centre. This is mainly because teachers have the crucial responsibility for developing or preparing the learning environment, choosing or designing instructional strategies and deciding what instructional materials or teaching aids to use (Moore, 1982). If teachers do not have the necessary knowledge and skills to integrate D&T into the curriculum as part of the instructional process, they cannot be expected to do so. Glenn and Carrier (1986) came to this conclusion on teachers who were expected to integrate computer technology into their teaching, but were experiencing difficulties. It was only after they had gone through a training programme designed to give them the necessary orientation that they showed signs of progress.



The experience in Zimbabwe has been that all teachers currently in the field and those in colleges and universities are only trained to teach Woodwork and Metalwork up to ‘O’ Level. Even those currently in the B.Ed. degree programme at the University of Zimbabwe (UZ), are not adequately prepared to teach D&T at ‘A’ Level since they only get familiarized with the phenomenon as an approach. During the national conference on teacher education, suggestions to address the situation included specially designed in-service programmes for the life-long professional development of teachers. Relevant authorities were urged to consider in-service programmes for technical subject teachers in order for them to cope with the challenge of technological changes in society (NCTER, 2000:21).

The advent of D&T in the Zimbabwean curriculum has also meant the proliferation of new perspectives relating to instructional practice in technical education (Kwaira, Kolsto, Meerkotter, & Ogunniyi, 2006). And, the intensity of problems associated with differences in perspectives among practitioners has resulted in a quest for continuous change and reform, especially now, at a time when educationists, the world over, are advocating for the active participation of learners in educational matters and activities. In most cases, educational reforms have been associated with the introduction of new instructional materials (Klein, 1980; Sevigny, 1987; Powell & Anderson, 2002). Therefore, the initial challenge for this study was to determine the actual areas of need, regarding the professional development of teachers in order for them to effectively teach specific aspects of D&T at 'A' Level. This then led to the design, development, implementation and evaluation of an exemplary package of instructional materials for a specimen in-service programme with serving teachers enrolled for the Bachelor of Education degree (B.Ed) programme in the Department of Technical Education at the University of Zimbabwe. During the preparatory stages of this study, several investigations were made at pilot level, culminating in a sixty hour modular course in Material Science (see Item 3.4.2 in Chapter 3 and Appendix 6).

During the national conference on teacher education (NCTER, 2000), several resolutions and suggestions were made and for this study, a three-fold challenge in the professional development of technical subject teachers was of particular interest, given the need to:



- increase scientific knowledge in order for teachers to approach and teach D&T from a scientific perspective.
- enhance the competence of teachers in solving practical D&T problems through scientific knowledge and principles.
- increase understanding of how to teach pupils to solve technical problems in D&T by putting theoretical knowledge into practice.

Such a paradigm shift called for life-long professional development, as opposed to the 'one-off' programmes in most Zimbabwean conventional colleges today.

Literature has shown several advantages of in-service programmes in the professional development of teachers (Coldervin and Naidu, 1989). In Zimbabwe, while the development of such programmes for technical subject teachers has concentrated mainly on traditional subjects like Woodwork (WW), Metalwork (MW), Building (BLD) and Home Economics (HE), not much has been done on D&T as a subject. The present study contributes to knowledge in the manner in which it examines the effect on learning of creating and using a specimen instructional package. It is a new idea that can arguably and safely be equalled to the creation of new knowledge, making a worthy contribution to the world of knowledge.

For the purpose of this study, the following pedagogical ideas were drawn from the aims and objectives of the 2002 version of the 'A' Level D&T syllabus:

- Problem posing as opposed to the traditional approach where learners were presented with solutions to problems
- Learners and teachers brain storming over possible solutions to practical problems
- Learners working in groups, thereby collaborating in the business of learning
- Teaching and learning being learner-centred
- Learners contributing towards the assessment of their own work through self-assessment
- Learners being able to record their ideas in design folios as they work on specific problems
- Learners experimenting with various materials in solving practical problems
- Promotion of subject integration between Material Science and other subjects in the curriculum, particularly sciences like Physics and Chemistry
- Technical subjects becoming more and more scientific in orientation within the context of D&T



The fear was that all these ideas would not mean much if the teachers who were expected to implement them in the curriculum did not understand or appreciate them. Hence an examination of the teachers' perceptions, understandings, and knowledge of these ideas would be important. Although one could design, develop, and implement an instructional programme of one kind or another, what was not so obvious, and required a deeper level of investigation, was the impact of such a programme on the professional development of the teachers in question. There was therefore a need to determine the effect of the MS course on the perceptions, understandings, and knowledge of the teachers regarding content in Material Science (MS) and instructional practice in Design and Technology (D&T), within the parameters of the outlined pedagogical ideas drawn from the 'A' Level D&T syllabus. The MS course developed in this study was also designed to enable teachers currently teaching Woodwork and Metalwork at 'O' Level to teach MS at 'A' Level within the context of D&T. Tilya and Voogt (2002) maintain that the development and application of curriculum materials facilitate curriculum change, as long as the practices of the classroom are taken into account.

## 1.2 RESEARCH QUESTIONS

The primary research question posed for this study was, 'What effect would a specially designed, developed and implemented Material Science (MS) course have on serving teachers in terms of their perceptions and knowledge/understanding regarding content in MS and instructional practice in D&T?' This question was posed in view of the three-fold challenge outlined under Section 1.1, encompassing specific areas of need in relation to the professional development of D&T teachers in Zimbabwe.



To effectively address the primary research question, it was necessary and useful to: (a) compare the teachers' initial perceptions, understanding and knowledge of specific aspects of D&T and concepts in MS to those they held on completion of both the MS and Machine Shop Practice (MSP) courses (objectives 1 and 2), and (b) determine the extent to which teachers applied their knowledge of MS (including scientific principles) during problem-solving activities under MSP (objective 3). Teachers were expected to reflect on their perceptions, understanding and knowledge of MS within D&T as they solved practical problems under MSP, thereby putting theory into practice. Hence the following secondary questions were considered in order to simplify the more complex primary question:

1. What perceptions of specific aspects of Design and Technology, as an approach, do teachers hold?
2. What knowledge/understanding of specific concepts in Material Science do teachers hold in relation to the teaching and learning of Design and Technology?
3. To what extent are teachers competent to apply the knowledge/understanding gained from the Material Science course in solving practical problems under the Machine Shop Practice course?

## 1.3 SOME PRELIMINARY THOUGHTS ON THE CONCEPTUAL FRAMEWORK (Early theoretical considerations)

Having considered all the issues surrounding the problem (causes, impact, possible solutions and outcomes), the next step was to put the study into the appropriate conceptual framework. The following areas were then studied before relating them appropriately within the context of this study:



### *1.3.1 The difference between 'education' and 'training' in the professional development of teachers*

In this study, the time prospective and serving teachers spend in colleges and universities was viewed as being for two main purposes; to be educated and to be trained. Therefore conceptually, the key terms; 'education' and 'training' needed explanation to avoid the confusion usually resulting from discussing them interchangeably. These concepts deserve treatment as separate entities which, although related in several ways, are fundamentally different and can be conducted separately. There was need to clarify the difference between 'education' and 'training' before highlighting their relationship within the context of teacher preparation/development. Logically, if there is a difference between 'education' and 'training', there must be a difference between 'teacher education' and 'teacher training'.

According to Peters (1973), ‘education’ is not an activity, and:

> We do not say, ‘go along, go and get on with your educating’, as we would say, ‘go along, go and get on with your teaching’ ... (p.15)

This means, ‘education’ is no more an activity than ‘reforming’ and ‘improving’ are. Hence the question; "What is it then?"

‘Education’, like ‘reform’, is not about picking specific activities, but laying down criteria to which certain activities must conform. And, activities that count as educating people are as many as those that count as reforming them (Peters, 1973). Therefore, to refer to activities as ‘educating’, implies them conforming to certain very general criteria. Both ‘education’ and ‘reform’ have a norm serving as a remote ideal for such activities (Peters, 1973).

On the other hand, the term ‘training’ suggests confinement, where people are prepared to be professionals in specific fields, such as: drivers, doctors, lawyers and teachers. No one is trained in a general way and this lack of specificity is exactly what education suggests. There is an inclination to deny that we could consider a person ‘educated’ after only developing an awareness or understanding of a phenomenon in a limited way. Our notion of an educated person is of an all-round individual possessing a ‘know-how’ and some understanding of principles (Peters, 1973). This implies that a person’s outlook is transformed due to what s/he knows and understands. One might be highly skilled as a teacher, and yet can still be considered as ‘uneducated’. ‘Teacher training’ underlines the teacher’s function as an agent for schooling, possessing special skills. However, all these attributes are still not enough since the teacher would still need to be educated in order to be an accomplished professional. This is why, even in this study, it was important for one to seriously consider how all the functions relating to both concepts: ‘education’ and ‘training’ could be balanced in the professional development of teachers. This also implied a balance between ‘theory’ and ‘practice’ in teacher preparation and development (Walker, 1982). Effectively ‘education’ would bring in the theoretical bit, while on the other hand, ‘training’ would introduce the practical bit. It is this orientation that influenced the design and development of the instructional materials used in this study, through debate and critical thinking. Even the idea of linking theoretical knowledge generated under Material Science (MS) to the practical experiences expected under Machine Shop Practice (MSP) was mooted from here.

### *1.3.2 The concept of design and technology education*

For the purpose of this study, there was need to define ‘Design and Technology (D&T) education’ and to do that, one had to be clear about the meanings of ‘Design’ and ‘Technology’, as separate entities in order to relate them accordingly within the context of D&T education. Fowler and Horsely (1988), whose position has been strongly supported by Roberts and Zanker (1994:5), argue: "---the view that ‘technology’ encompasses ‘design’ is quite incorrect and should be resisted". Roberts and Zanker’s (1994) view differs from Williams (2002), who considers ‘Design’ to be part of ‘Technology’, featuring as one of the many processes appropriate to Technology. On the other hand, Roberts and Zanker (1994) recommend an understanding of these terms separately before explaining the link between them or their relationship within D&T education. McComas (1996), McCormick (1996) and Petroski (1996) refer to ‘Design Education’ on the one hand and ‘Technology Education’ on the other. In this study, Roberts and Zanker’s (1994) position regarding the separation of ‘Design’ and ‘Technology’ was found to be preferable for the sake of clarity. However, although I did not totally agree with Williams (1996) on the issue of ‘Design’ as simply being a process under Technology, I agreed with his idea of perceiving ‘Technology’ as a thoroughly integrated activity where ‘content’ and ‘process’ and/or ‘theory’ and ‘practice’ are not viewed as separate entities. Where the issue of ‘process’ was to be considered, I preferred the view where one would refer to the ‘design process’ in its own right on the one hand and the ‘technology process’ on the other. And from there, one would then perhaps refer to the ‘design and technology process,’ just like we would talk of ‘Design and Technology Education’ after combining ‘Design Education’ and ‘Technology Education’. Therefore, this is the position that was chosen in this study regarding these concepts/phenomena.

Fowler and Horsely (1988) maintain that 'design' is an activity in which a wide range of experiences, knowledge, and skills are used to find optimum solutions to given problems within specific constraints. According to this contention, the activity involves identifying and clarifying a problem, making a thoughtful response, and then creating and testing one's solution. Beyond this point, one might modify his/her solution so that the process of designing begins again, depending on the results of the tests. For example, if the solution has been successful, the process comes to an end but if not, the process resumes and continues into more cycles until an acceptable solution is achieved. Fowler and Horsely (1988) also describe 'design' as a creative activity where one may use known facts or solutions, but the way one combines these to solve a given problem requires creative thinking. Given this observation 'design' appears to be a comprehensive problem-solving activity, involving the whole process of producing a solution from conception to evaluation. This includes elements such as cost, appearance, styling, fashion, and manufacture. Designers work in almost every area of life: for example, product design, graphic design, interior design, engineering and environmental design. Each area requires a different type of knowledge, but they all involve similar design activities (Fowler & Horsely, 1988).



While 'design' has to do with creative thinking in problem solving, 'technology' on the other hand has to do with the application of the hardware or equipment in problem solving (Kwaira, 1998). However, this view of 'technology' is not to be confused with what Layton (1974:31) sites from Singer, Holmyard and Hall's (1954:58) monumental 'History of Technology' defining 'technology' as, "--- how things are commonly done or made" and "--- what things are done or made". Layton (1974) criticises this definition and suggests that it treats 'technology' as techniques and technologists as technicians. He further argues, "--- in this case, the traditional definition of technology as 'systematic knowledge of the industrial arts' becomes meaningless" (Layton, 1974:31). However, the editors of the controversial 'History of Technology' have argued that it was not until the 19$^{th}$ century that 'technology' acquired a scientific content and came ultimately to be regarded as almost synonymous with 'applied science' (Daumas, 1969:68).

The view that was adopted in this study regarding technology was derived from deliberations by McCormick (1996), Lewis (1995), Hennessey and McCormick (1994), Aikenhead (1989), Mulberg (1993), Zoller (1992) and Meunier (1980). According to this view, 'technology' and certainly 'Technology Education' has been characterized as more of an activity than a discrete body of content. According to McCormick (1996) 'techno-logical knowledge' is divided into 'procedural knowledge' which relates to the activity, and 'conceptual knowledge' relating to the body of content. There appears to be more international consensus among technology educators on the activity of technology than on the content of technology (Hennessey & McCormick, 1994). Most people agree that 'technology' is the know-how and the creativity to use tools, resources and systems to solve problems and to enhance control over natural and man-made environments to improve the human condition. One might be creative enough to think of a solution to a problem, but without relevant equipment, the whole thinking process becomes a waste of time. That is why it is important to consider the link between 'design' and 'technology'. The need for such a link is justified by the belief that we cannot have a complete solution to a practical or technical problem without the two coming together (Kwaira, 1998). Another way of relating these two concepts is to consider their scientific orientation. It has been argued that they both involve the domain of 'Science' (Roberts & Zanker, 1994). For example, for one to effectively engage in 'design' as activity or process, that person is likely to manage better if guided by scientific principles in his or her decision-making. This has to do with one's way of thinking (Kwaira, 1998:224-229). On the other hand, 'technology' becomes scientific when principles; especially those relating to Physics and Chemistry are used to develop the tools, equipment and materials employed in problem-solving (Kwaira, 1998:224).

Grappling with the confusion between D&T as an approach in the teaching and learning of traditional technical subjects like Metalwork or Woodwork, and D&T as an independent subject has not been unique to Zimbabwe. This has also been the case in various other contexts (Kwaira, 1998:224-229). However, despite a few areas of fundamental differences in terms of impact and impression within the curriculum, D&T still means more or less the same thing when it comes to the kind of orientation one ends up with after going through the theory involved in either the subject or the approach (Kwaira, 1998:224-229). For example, the underlying philosophy has to do with the promotion of 'creativity' and 'problem-solving' (Davies, 1996). Instead of presenting learners with solutions to problems, they are presented with problems for which they are expected to seek solutions through thoughtful and systematic investigations. Since this orientation features in both the approach and the subject of D&T, what happens within the Woodwork and Metalwork syllabi at 'O' Level was in this study considered to be a foundation of the proposed 'A' Level syllabus. Similarly, what happened at pre-service level of teacher training was also considered to be the foundation of what was going to happen at in-service level. This view was found to be very much in agreement with the belief held by Glenn and Carrier (1986) that in-service training programmes are very dependent upon the initial training received at the pre-service level. According to this belief, pre-service training is the basis upon which any progressive in-service programme is developed.



### *1.3.3 The provisional instructional design model (Early thoughts)*

This study was about designing and developing instructional materials for the professional development of teachers in D&T, with specific reference to 'Material Science'. In principle and/or rather generally, the whole process is usually based on a particular model, depending on one's design. For the purpose of this study, the model used was anchored on one mainly adapted from Ally's (1997) version comprising seven developmental stages (Figure 1.1).

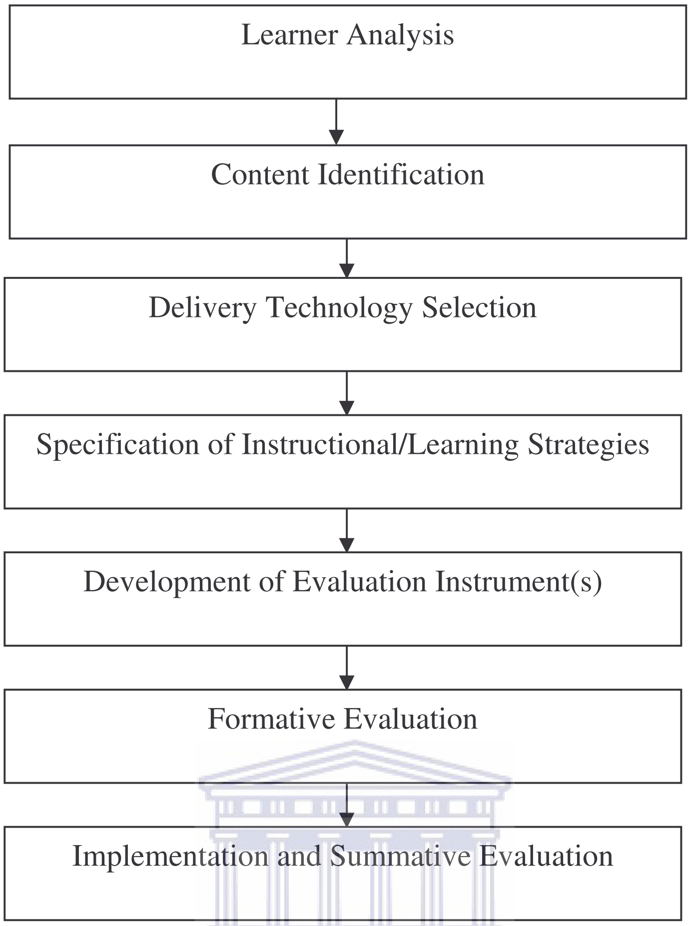





**Figure 1.1** Ally's instructional design model adapted from Romiszowski (1981a.) and Dick and Carey's (1996) models

Ally's model is a summary of two models, one by Romiszowski (1981a.) and the other by Dick and Carey (1996). While the former comprised: Problem definition; Problem analysis; Design; Implementation; Evaluation and Standardization of the improved solution, the latter comprised of: Determine the instructional goal; Analyze instructional goal; Analyze learners and contexts; Prepare performance objectives; Prepare assessment instruments; Specify instructional strategies; Develop and select instructional materials; Conduct formative evaluation; Revise the instruction and Conduct summative evaluation. It is the six stages from Romiszowski (1981a.) and the ten from Dick and Carey (1996) that Ally (1997) collapsed into the seven in Figure 1.1. Despite differences in the number of stages and terminologies used to label the stages, Ally (1997) carefully and closely examined these two models and concluded that they had the same outcomes, hence the decision to combine them into only seven stages. There was a lot to learn from this model, leading to subsequent modifications and developments in search of an ideal version for the purpose of this study. What was required was a suitable instructional design model that would enable the design, development, production, implementation, and evaluation of the whole programme of instruction.

According to Figure 1.1, the process starts from ‘Learner Analysis’ and filters, stage by stage, right down to; ‘Implementation and Summative Evaluation’. Given the sense behind the arrows, this is a one-way kind of progression, implying one strictly following the order or sequence as faithfully as possible.

Although the model in Figure 1.1 was a useful starting point, it still needed fine tuning in order to satisfy the needs and demands of this study. The model was still far from being final. This meant further search and consultation of literature where the following areas were considered relevant and therefore deserving attention as reflected in Chapter 2: the context of curriculum change and innovation; the implications of change on teacher education and training; ‘values’ within the context of design and technology; in-service education and training in the professional development of teachers; current issues in design and technology education; current debate on educational aims and goals; teaching and learning within the context of design and technology; instructional systems in teacher education and training; the design and production of instructional materials for the professional development of teachers; the importance of instructional materials in teacher professional development, and further thoughts on the instructional design model (revised perspectives from new insights).

# Chapter 2

# SOME THEORETICAL PERSPECTIVES FROM LITERATURE AND FURTHER INSIGHTS INTO THE CONCEPTUAL FRAMEWORK

This chapter is based on the literature search conducted during the early stages of this study. As indicated in Chapter 1, issues of interest were particularly focused on the following areas:

- The context of curriculum change and innovation
- Implications of change on teacher education and training
- 'Values' within the context of Design and Technology
- In-service education and training in the professional development of teachers
- Current issues in design and technology education
- Current debate on educational aims and goals
- Teaching and learning within the context of Design and Technology
- Instructional systems in teacher education and training
- The design and production of instructional materials for the professional development of teachers
- The importance of instructional materials in teacher professional development
- Further thoughts on the instructional design model (Perspectives from new insights)

The main idea behind focusing upon and studying these major areas was to seek clarification on issues relating to: methodology (e.g. instruments, sample selection or identification of subjects/participants, data collection and analysis), presentation of results/findings and the conceptual/theoretical framework that informed the whole study. Under each area, specific questions guided the literature search by maintaining focus and direction. However, these questions are not to be confused with the secondary research questions generated for this study. The questions were simply meant to guide the literature search under specific areas where they helped to put the whole study into appropriate context.

## 2.1 THE CONTEXT OF CURRICULUM CHANGE AND INNOVATION

The following questions guided the literature search:

- What factors necessitate change and innovation in the curriculum?
- In what way is the content important in curriculum change?
- Who decides or determines what goes into the curriculum?
- What is the relationship between society and the curriculum?



'Curriculum change and innovation' has to do with the question of 'relevance' (Browers & Flinders, 1990; Maslow, 1970; Ornstein, 1992). It is usually necessitated by the need to make the curriculum relevant to a particular context (Hanson & Brembeck, 1966; Ornstein, 1992). According to Cornbleth (1986), calls for reform signify dissatisfaction, impatience and optimism. This assertion seems to suggest and confirm the belief that people are rarely content with things as they are. Naturally people always expect greater quantity and quality than whatever presently exists (Cornbleth, 1986). In education and schooling, this explains the vitality that we always witness in the continuous search for excellence. The curriculum is always under the spot-light and is challenged to keep abreast of events in society, which are sometimes unpredictable (Apple, 1990). Since different politico-socio-economic situations exist in different countries, educational problems tend to be relative, depending on the particular needs of individual societies (Apple, 1990; Cuban, 1990; Kohl, 1991). This in turn introduces the issue of 'curriculum relevance', where English (1983) views the curriculum in terms of ideological (or philosophical-scientific), technical (or design), and operational (or managerial) issues.

According to Barrow (1984), to argue that curriculum should be relevant or useful does not mean much in itself because we need to know whom it should be useful to, what purpose it should be useful for, and in whose judgement it should be useful. Barrow (1984) goes further to assert that activities do not possess or lack relevance in the abstract. They possess or lack relevance to particular people, for particular purposes, and in particular circumstances. In this case, society and the individual are of particular interest.

It is widely held that the content of the curriculum depends on the nature of society (Freire & Macedo, 1989; Wiles, 2005). Any society sophisticated enough to have an idea of education is most likely to regard some knowledge and some skills as worthy of passing on to the next generation (Barrow, 1984; Rogers, 1983). What is judged as valuable depends on several factors where, among many, Kelly (1980) gives; different epistemological styles, different cultures, and different stages of development. Moore (1982) also refers to a position held in recent years by some sociologists of education who, following a Marxist persuasion, maintain that any educational curriculum reflects an interest. Hanson and Brembeck (1966) confirm this observation:

> In its educational investment, a country must adopt a balanced program suited to its own needs and stage of development or it may run into trouble ... (p.148).



Apart from society we also have the ‘individual learner’ considered under the issue of ‘curriculum relevance’. Whatever the context, the learner is the key to the success of any curriculum (Garforth, 1966; Kwaira, 2000). According to this point of view, society might endeavour to achieve certain ideals but, if the learner’s interests are not accommodated, not much might be achieved! Garforth (1966) goes further to point out that politicians, policy makers, school administrators and teachers might agree on what they might consider to be a wonderful curriculum, only to find the wrong students showing up! Garforth (1966) appears to agree with Kilpatrick’s (1926) observations, focusing on the ‘child-centred curriculum’, which according to Ginsburg (1986), belongs to the doctrine of ‘child-social-purpose’, based on the ‘activity-centred curriculum’.

Perhaps, Kilpatrick’s (1926) work could best be explained by the more recent debate raised by Berlak and Berlak (1981) and Berlak and Berlak (1983), focusing on three main dilemmas from among several, regarding the choice of knowledge patterns in a curriculum: (a) knowledge as given versus knowledge as problematic, (b) public knowledge versus personal knowledge, and (c) knowledge as molecular versus knowledge as holistic. Given the profile of controversies and contradictions implied in these areas, the direction one takes depends on one's line of thinking, resulting in a particular outlook of the curriculum to be followed in a particular context. McNeil (1990) has drawn similarities between Kilpatrick's (1926) work and that of Dewey (1929). However, the main difference that McNeil notes between these two architects or philosophers of education is that while the former (Kilpatrick, 1926) focuses on the role of the child in an educational enterprise/activity, the latter (Dewey, 1929) focuses more on the teacher's role. For Kilpatrick (1926), the child has to learn to search or investigate --- compare --- think why --- and in the end make his/her own decision as required in a given situation. According to the thinking in this study, this is exactly what D&T is all about!

We usually think of a curriculum as having high standards if it covers ground, requires much and difficult reading, demands many papers and if the students for whom it is intended do not easily get 'good' grades. According to Garforth (1966:27), what one needs to ask of a standard is not, "is it high or low?" but, "is it appropriate to one's goals?" If one's goals are to make people more alike, to prepare them as docile functionaries in some bureaucracy, and, to prevent them from being vigorous, self directed learners, then the standards in most of our schools are neither high nor low; they are simply apt. If the goals are of a new progressive education, one needs standards based on the actual activities of competent and confident learners, genuinely engaged in learning (Garforth, 1966). This point was found central in the design and development of the instructional resource package behind this study. The needs of those teachers who were involved, in terms of learning, were taken seriously, especially in view of the fact that there were specific values and attitudes that they were expected to later transmit to the pupils they were going to teach in their respective schools. These were particularly emphasized within the structures of the course outline as adopted from the 'A' Level D&T syllabus.



Davis (1976:59) maintains, "Any talk about high standards from teachers and school administrators is nonsense, unless they are talking about standards of learning". He argues that children should be taught how to learn instead of only being given what to learn. Paulo Freire supports such an approach when he advocates for 'Problem-posing' as opposed to the 'Banking concept of education' (Kwaira, 1989).

Barrow (1984) identifies four causes of irrelevance in education and consequently, four levels on which relevance may be achieved: what is taught, how it is taught, learners' feelings and the learners' concerns. In practically all societies, rapid change is occurring in roles and relationships, economic conditions, mores and values, religious and political beliefs, relations between nations, and ways of everyday life (Moore, 1982). These and other changes implicitly and explicitly challenge us to re-think the curriculum (Bowser, 1983). In most cases profound changes are needed in school curricula and in government policies to meet the challenge, hence the need for reform(s) in education, both 'radical' and 'gradual' (Zvobgo, 1986). In Zimbabwe, the latter, also known as 'continuous or rolling' reforms are currently the main focus in view of the need to have the education system in line with the prevailing politico-socio-economic conditions.

The need for such continuous revision of the curriculum is actually related to the rapid and erratic shifts, qualitatively and quantitatively, in the 'social demand' for education as well as in the 'economic demand' for educated people (National Conference on Teacher Education Report, 2000:1). Hence, it is affirmed, if 'rolling reform' is to have any meaning or impact, it must be possible to identify, and to some extent predict, such shifts [National Commission for Excellence in Teacher Education (NCETE), 1985]. This means that a society, which is rapidly changing, also needs a different kind of education from that which is sufficient in a static society; if ever there is one. In most countries today, the majority of citizens must be prepared to change occupations once or twice during their working lives, or to undergo a so thorough re-training that it may be considered equivalent to a complete change of occupation. There is also constant development and change in the subjects and the materials used in education. All these developments affect the context in which the work of the school is performed (Powell & Anderson, 2002:107-136). It is becoming less important for us in schools to devote our time to the teaching of facts that probably will soon become obsolete. By implication, in Design and Technology

(D&T), the practical skills we teach have to be up to date and relevant; otherwise they would not be applicable in problem solving. Where technological advances occur, for example in industry, what we teach in schools particularly practical skills would accordingly need to be stream-lined in order to keep abreast of events in the world of work.

Discussing 'aims of education', Barrow (1984) warns us of the danger of 'inert ideas', and argues that education founded upon such ideas is not only useless; it is above all harmful. Perhaps, it could pay off to have teaching in a progressive school concentrating more on answering the questions 'why?' and 'how?' than 'when?' and 'where?' It is important that schools provide pupils with particular fundamental skills and the capacity and desire to learn new phenomena (Kliebard, 1982). According Barrow (1984), such learning should not only occur in the classroom with teachers, but also at home where pupils work on their own. This would prepare them for further education and re-training; natural features of the lives of most adults today (Kwaira, 1989). The field of curriculum is a synoptic one where the specialist or practitioner brings perspectives from other fields to bear on curriculum (Kliebard, 1989). This appears to suggest that, the curriculum designer examines and uses the concepts, methods, and research tools of the philosopher, historian, psychologist, sociologist, economist and political scientist in his/her work.



Rolling reforms in education are also justified by the need to increase productivity in the system. Education is sometimes thought of as one main determinant of the 'residual' factor in economic growth [Organization for Economic Co-Operation and Development (OECD)-SWEDEN, 1967]. There is a strong correlation between a country's educational efficiency and its economic productivity (Hanson & Brembeck, 1966).

In common with schools, the institutions involved in teacher education and training are affected by the prevailing climate of educational change in respect of teaching methods, organization of activities and content of the curriculum. As observed by Taylor (1969), the manner in which innovations are brought about, the extent to which the institutions responsible for preparing teachers are themselves innovating agencies, the existence of a lag between the introduction of new ideas and the responses of colleges to them, are all matters on which there is generally an absence of solid information. Comment on them is usually speculative. This could also be true of Zimbabwe since there have also been several grey areas and problems relating to the whole education system, especially teacher preparation.

## 2.2 IMPLICATIONS OF CHANGE ON TEACHER EDUCATION AND TRAINING

The following questions guided the literature search under this section:

- What role do teachers play in an education system?
- What is the role of teacher education in a rapidly changing Zimbabwe?
- How has the current politico-socio-economic situation in the country impacted upon teacher education and training?



Success in the implementation of curriculum requires that teachers be appropriately prepared in terms of education and training (Cornbleth, 1986). This assertion seems to suggest that curricula reforms in teachers' colleges be aligned to those in schools; a position that was highly regarded in this study. According to Cornbleth (1986), most school reform reports provide background for the subsequent calls for reforms in teacher education. Therefore, teacher education reform proposals are, in this study viewed as responses to school reform reports. The reforms and innovations dealt with had to do with the shift from the traditional approach in the teaching and learning of technical subjects to the more progressive D&T approach, as already observed in Chapter 1.

Referring to the United Kingdom, George (1994:8) has argued, "If the UK is to have world-class technological skills we need to make Design and Technology teaching in our schools world-class too". Drawing lessons from this statement, in Zimbabwe perhaps we could also say the same, now that there is such a serious attempt to popularize the teaching and learning of D&T in schools. However, the question is, 'How can we have world-class teaching without a properly trained and well-motivated teaching force?' Learning from George's (1994) experiences, it appears we cannot have world-class teaching without such a teaching force. Currently, such a teaching force does not seem to exist in Zimbabwe.

There are important techniques and skills that must be mastered by those wishing to teach. Unless there is a deliberate primary emphasis on the ends that such means are intended to serve, and a searching exploration of the connection between schools and the society that surrounds them, these techniques and skills exist in a vacuum (Barrow, 1984). Barrow complains about such an emphasis generally lacking in teacher education, resulting in teachers, seeing themselves as mere implementers of educational policies conceived and directed by others. This is a very interesting observation which I strongly feel requires special attention from a more global and holistic outlook. Given this observation, I had to make a review of my position as a teacher educator interested in promoting special techniques and skills in the serving teachers who were under my responsibility; the people I intended developing into effective professionals. As I was planning this study, one question that came to mind was, 'If there are special techniques and skills to be mastered by those I teach, what special techniques and skills should I have as a teacher educator?' I consulted Zimpher (1974) who led me to an answer by posing the following questions: What should be the goal of the education for teacher educators? How should teacher educators be educated? What should constitute the curriculum for teacher educators? Who should be a teacher educator? How can the professional growth of teacher educators be ensured? How can the education of teacher educators be evaluated? Although these questions did not provide a direct answer, they helped me to reflect on my role as a teacher educator, and had a bearing on what I was setting out to do with the serving teachers in this study.

According to Taba (1962) and Curle (1970), teacher education is one of the nerve centres of an educational system. More can be done to raise standards of education at less cost through teacher-education than any other activity. In many developing countries however, relatively little attention has been paid to the urgent need to improve teacher education (Kwaira, 1989). In some countries, it is not just teacher education and training that need careful attention but also the establishment of an esprit de corps for the whole teaching profession (Curle, 1970). This seems to suggest that any reform in teacher education and training means changing the whole network of relationships since the two go hand in hand. A proper profession cannot easily be created by an under-privileged, low status, poorly trained body of practitioners (Curle, 1970). For any reforms in an education system to be implemented with a reasonable level of success, teacher education and training must be included. This assumption is actually based on the premise that teachers are among the most important players in any reforms that affect schools and their curricula, both at national and school levels (Curle, 1970; Tanner & Tanner, 1975). Most reforms fail to achieve their goals not because they are badly conceived, but because of poorly planned implementation strategies, especially when teacher education and training programmes do not reflect realities in schools (Taba, 1962; Curle, 1970; Tanner & Tanner, 1975).

The tasks of teachers in a rapidly changing world have become much more complicated than ever before (Lauglo & Lillis, 1980). For example in Zimbabwe, it appears the problem is no longer merely one of adapting buildings, books and equipment to conditions of continuous change, but of enabling teachers and other educationists to cope with the demands that these conditions are creating on them. Lauglo and Lillis (1980) affirm that it is in this context that colleges of education and universities must produce the teachers of tomorrow, and it is against this background that the current programs in these institutions must be evaluated. This point is further reinforced by Gorman and Hamilton (1975), who suggest such evaluation being in the form of follow up studies where graduating teachers are followed and studied in their working environments.



Given the basis of a process of change where there is no likelihood of any diminution in the pace of technological innovation during the foreseeable future, it becomes necessary for us in Zimbabwe to prepare for a situation where rapid change is a permanent characteristic of the social environment, with inevitable consequences upon the curriculum, methods of teaching and school organization. From this background, one could perhaps ask; “In Zimbabwe, where does teacher education and training stand? Is it keeping pace with changes in educational policy in schools and in the world of work?” These questions were in part answered during the literature review that was conducted in this study.

## 2.3 'VALUES' WITHIN THE CONTEXT OF DESIGN AND TECHNOLOGY

The following questions informed the literature search under this section:

- How does the issue of values feature in D&T education?
- How does the issue of values in D&T education feature in various societies?
- How does D&T affect our lives?
- What responsibilities do designers and technologists have to society?
- To what extent are designers and technologists accountable and answerable for their actions and activities in society?
- How do we strike a balance between the positive and negative effects of D&T on society?
- How do people relate in terms of differences on value systems?



According to Fowler and Horsley (1988), a world without calculators, television, radio, trains, cars, aeroplanes, house insulation, advertising, shopping precincts and microwaves is difficult to imagine. Although Fowler and Horsely (1988) make this observation from the stand-point of a particular context regarding for example, level of development, the same could be said of various other contexts with the only difference perhaps being in the nature of gadgets and services focused upon. Since societies differ with regard to situations, needs and problems tend to be relative and the same goes for solutions to specific problems. Simply put, the point appears to be the fact that such products and services have by and large benefited us in terms of quality of life. It is impossible to apply 'design' and 'technology without changing the world in which we live (Fowler & Horsley, 1988). They bring about change which affects society and civilization, either positively or negatively, hence the impact on cultural values. It therefore follows that, "designers have responsibilities to society because --- their work affects us" (Fowler and Horsley, 1988:3).

According to Bonsiepe (1991), 'design' is a strategic activity where, apart from solving national problems, designers work under timing, financial, and political pressures. The argument remains, 'they must still and always place people first in whatever they do'. Fowler and Horsley (1988) propose the careful management of technology. This implies a lot for practice in D&T where, special activities like 'market research' and 'evaluation' are designed to accommodate the views of clients during product development through consultation of specific interested parties.

Fowler and Horsley (1988) give examples of how the benefits of technology sometimes turn into problems in the absence of careful management. One such example is the case, where 'having improvements in medical science causing people to live long might not immediately appear to be a problem, but if we consider that many people will live longer in retirement than ever before, then it becomes an economic crisis'. However, today this argument needs a revisit, given the tragic path being cut by the scourge of the HIV-AIDS pandemic across the globe. Although during the 1980s, there was talk of this pandemic, as Fowler and Horsley presented their argument, the problem has drastically shifted to a more vicious posture today, especially here in Zimbabwe and many other developing countries where the situation is worsened by poverty. In Zimbabwe, this problem has already caused havoc in the education system, regarding human resource shortages.



Life styles must change if people are to come to terms with technology (Bhagavan, 1990; Waks, 1994). In order to manage technology, Fowler and Horsley (1988) recommend a shift of emphasis in terms of employment and deployment of the workforce. For example, many people might be required to work in technological industries to produce the technology that supports those industries. On the other hand, where jobs might best be done by machines, workers should be occupied in tasks which are better suited to being done by human beings (Waks, 1994). In fact, many traditional occupations are likely to disappear and be replaced by new ones. Living with technology, for most people today in Zimbabwe, now appears to mean coming to terms with change. On all this the bottom-line remains; 'the use of technology requires people to be responsible for their actions'. Fowler and Horsley (1988) observe that over the last century several countries especially those in the first world, have been irresponsible in dealing with various forms of pollution; natural resources have been taken out of the earth and the landscape has been scarred with spoil heaps and waste products; and, toxic chemicals have been released on the land, into the air and the sea. These observations have been confirmed by Pickering and Owen (1994) in their discussion of what they have termed, 'Climate Change and Past Climate'. They blame all natural disasters associated with climatic change befalling us today on selfishness and carelessness in the way we handle environmental issues like air and water pollution. There has been evidence to prove that we (the human race) are not managing the earth well enough. According to a British Broadcasting Corporation (BBC) World News Bulletin of the 30th of January 2007 at 0600 hours (Zimbabwe - time), most countries around the globe are already grappling with the adverse effects of global warming, which is worsening at a faster and greater rate than ever anticipated. Examples of special cases indicating the magnitude of the problem have been noted and highlighted from several countries in Europe, where icy and snowy conditions are no longer occurring as expected around specific times of the year or according to normal seasons (BBC World News, 2007-01-30).



From what we have seen so far, it is clear that technology has much to offer the world, but it has also been clear that it comes with a price. Therefore, the act of responsibility in terms of control and management is required if we are to get the best out of it. Lewis (1995) describes and explains, with concrete evidence, how 'technology' as a concept has benefited developed countries like Sweden, Britain, Germany, Japan, the Netherlands, and the United States. He also elaborates on how these benefits have been realized on various fronts, particularly in the health and the industrial sectors where life has become easier as a result of the application of technology in its various forms. With proper control and sense of responsibility, technology could be the hope for the future and a way of life for future generations (Lewis, 1995). It is only unfortunate that some industrialized countries in the first world have been found to be irresponsible in their technology related activities. For example, according to Pickering and Owen (1994), the whole world is now grappling with problems related to the depletion of the ozone layer, water pollution, air pollution and acid rain. Given this situation, Waks (1994) proposes the introduction of education in 'Technology and Values' at all levels of the curriculum if D&T education is to benefit us in the long term. He highlights a dominant approach where such education would involve the study of 'critical issues' to encourage broader awareness and responsible social action among learners. In this case, units of study are organized around technological issues such as nuclear power, third world technical development, or technology-induced development. Examples from the mid-1980s include the ‘Innovations Course’ designed by the Biological Science Curriculum Study in the United States, and the PLON physics course in the Netherlands (Waks, 1994). For us here in Zimbabwe, ‘Education for Living’ programmes could be enriched by the inclusion of such education (Education in Technology and Values).

According to Waks (1994), since the 1960s, the social images of science and technology have changed in important ways. Post-modernism, post-materialism, and post-industrialism are some of the terms in which these changes have been conceived. These ideas and parallel changes in technology assessment assist us in re-situating value judgment and social action in technology studies. For example, Foucault (1980) defines and describes the ‘post-modern period’ as a time when the idea of progress within rationality and freedom disappears with the withdrawal of faith in science and technology, and the liberal institutions which supported their development. In agreement with Foucault (1980), Waks (1994) argues that forms of knowledge are components in the development and extension of regimes of social power. Both Waks (1994) and Foucault (1980) have supported projects directed at marginal groups in their localities and neighbourhoods, where among several groups, prisoners and street children have been the main focus. They have however avoided commitment to universal values or grand narratives of progress. Such post-modern themes have been echoed in the interdisciplinary field of science and technology studies. Latour (1987) for example, de-constructs idealizations of scientific and technological knowledge through field studies of knowledge construction processes which reveal ineliminable but arbitrary roles of consensus building, negotiating, and compromise in the making of ‘knowledge’. These studies appear to deny an epistemologically privileged place to science and technology.

On ‘post-materialism’ Waks (1994) observes that the new social movements since the 1960s have raised issues cutting across the social class divisions which traditionally shaped party politics in industrial democracies. While both working and managerial-professional classes depended upon economic growth and technological process, the social movements have focused on concerns which question these goals; for example, environmental protection that limit industrial growth. Related shifts can be noticed in themes of the new social movements; alternative lifestyles, means of health care and new ways of dying, for example (Waks, 1994).

Turning to 'post-industrialism', Waks (1994) observes that the notion held by Daniel Bell, about a post-industrial economy in which theoretical knowledge will replace the material techniques of the industrial era may have been over-drawn. However, the new 'intellectual technologies' he refers to are certainly transforming industrial production around the world. Computers and telecommunication technologies permit the rapid shifting of capital to find the highest return, as well as the rapid shifting of production sites to find the lowest labour and material costs (Waks, 1994). And indeed, technological 'competitiveness' in world trade remains a major political concern; for example, the recurrent trade wars between the United States and Japan or between the United states and China. Waks (1994) also argues that the post-industrial situation has severely eroded the social and economic security achieved by workers in the older industrial democracies. A second generation of new social movements guided by the slogan, 'together we stand' as propounded in the United States is responding to these concerns. Waks (1994) sees the interactions between the first and second generation social movements as being complex. For example, the latter also proclaim environmental rights for workers in the third world, but only to 'level the playing field' by reducing the cost advantages of anti-environmental production. In view of these observations, it is important for one to consider the implications of the conclusions arrived at. On areas relating to the nature of technology and the appropriate form or content of school curricula for technology education, there appears to be a recognition that 'values' are a central component or issue.



According to Prime (1993:30);

> ... there is a sense in which technology, both its products and its processes, represents the embodiment of the culture. We create the things we value, the things we think beautiful or useful. We device tools, machines and systems to accomplish the ends we value ... Our beliefs, our values, our philosophies, our experiences, in short our culture, is made manifest, in part in the artefacts and systems we create ...

This argument by Prime (1993) was in support of Conway's (1992) observation where 'technology practice' entails the organizational aspect, the technical aspect and the cultural aspect; where culture refers to values, ideas and creative activities. One way of viewing this area of educational experience is to consider it as a progressive refinement in the art of making 'value judgments'. Such judgments are usually characteristic of the world of practical action where what is regarded optional is determined by the way constraints are defined and values are assigned priority (Doll, 1992). The centrality of value judgments in the practice of technology has important educational implications as Pacey (1983:5) notes:

> If people are to understand and have some control over their own and other people's designs and technological activity, the assumptions underlying their value judgments need to be made explicit and debated...

An important aspect of capability is one's readiness to address the pertinent and sometimes implicit, often conflicting values with confidence, autonomy and responsibility. Hence, according to Conway (1992), Technology Education should at least include the following:



(1) Opportunities for the young people themselves to be creative and cooperative, in a process that develops sensitivity to other people's needs and cultures.

(2) Designing and making tasks set within a wide range of different contexts relevant to the lives and relationships of young people, not only in the context of producing consumer products but also in other spheres of social relations.

(3) Strategies that help young people explore the interaction of technological projects with their surroundings so that constraints and evaluation criteria take account of the environmental, social, moral and spiritual implications.

(4) Time given to modifying and repairing existing products so that users can become actively involved and resources are conserved.

(5) Consideration of technology practice in society as 'it is only an informed and technologically literate citizen who would be able to make decisions about technology

and assess its broad social impact on; family structure, inter/cross-cultural relations, national/international functioning, economic impact on business, commerce and government, as well as its environmental impact on agriculture, food production, and waste disposal, in both the short and long term'.

In view of the above requirements for Technology Education, teachers in training should have the opportunity to explore underlying assumptions in their teaching, depending on the specific course outlines that they would be working with in their respective subject areas. In fact, nearly all of Pacey's assertions are reflected and implied in the aims and objectives of the proposed 'A' Level D&T syllabus in Zimbabwe; and the same applies to the two 'O' Level syllabi (Woodwork and Metalwork) where some of these traits have been highlighted in various places. Bearlin (1987) maintains that good teacher education necessarily implies enabling future teachers to think about and justify what they will be doing as teachers in terms of fundamental beliefs about human beings, society, nature, knowledge and ethics. This is essential if they are to be autonomous in the sense of being able to take responsibility for their actions as teachers, especially on issues relating to cultural values within the context of D&T. In the teaching of technology, teachers need models that help them to approach technology together with its social and scientific contexts (Bhagavan, 1990; Layton, 1993). This means, they need encouragement to include reflection on moral values and social relations reified in technological objects. In fact, it needs a teacher education based on technological understanding beyond specialized expertise (Bhagavan, 1990; Layton, 1993).



Lastly, there are also implications for the school, where the aims it formulates for its technology curriculum should be explicit about underlying values and about the meanings attached to purpose and quality, in addition to technical aims. Insights generated here helped to clarify on the focus of the study, regarding the place of values in relation to knowledge and understandings or perceptions within the context of D&T; particularly, the cultural, social, religious and even economic values. Reference to the 'place of values', in this case implies the exact areas within D&T where one would actually and deliberately promote specific values as the situation might allow within a given context.

All the issues addressed in this section have a bearing on the three main areas of foci outlined in Chapter 1, in view of the need to:

- increase scientific knowledge in order for teachers to approach and teach D&T from a scientific perspective.
- enhance the competence of teachers in solving practical D&T problems through scientific knowledge and principles.
- increase understanding of how to teach pupils to solve technical problems in D&T by putting theoretical knowledge into practice.

## 2.4 IN-SERVICE EDUCATION AND TRAINING IN THE PROFESSIONAL DEVELOPMENT OF TEACHERS

The following questions guided the literature search under this section:

- What is the current situation regarding the training of technical subject teachers in Zimbabwe?
- What is the role of in-service training in teacher education?
- What models of in-service teacher education and training have been used in various contexts (including experiences from other countries)?
- What is the situation regarding in-service courses for teachers in other subject areas in Zimbabwe and how does that situation compare with that for technical subject teachers?

### *2.4.1 The education and training of technical subject teachers in Zimbabwe*

The first college to train technical subject teachers for African secondary schools in Zimbabwe, then Rhodesia was Gweru Teachers' College (G.T.C), after opening in 1965 (Murira, Keshav, Mandizha, Gwarinda & Stringer, 1983), followed by Belvedere Technical Teachers' College (B.T.T.C.) in 1983, three years after independence. The most recent was Chinhoyi Technical Teachers' College (C.T.T.C.) established in 1987 to make a total of three colleges, responsible for training technical subject teachers.

All along, these colleges have been offering certificates and diplomas in education, in association with the University of Zimbabwe's Department of Teacher Education in the Faculty of Education. However, recent developments have resulted in some of these colleges evolving into university colleges, offering Bachelor of Education degree qualifications in various subjects, including the technical. Before this development, after their certificates and diplomas in education, technical subject teachers have been pursuing this degree at the University of Zimbabwe, in the Department of Technical Education.

With so many university colleges sprouting around the country, the University of Zimbabwe is likely to end up focusing more attention on teacher professional development at Master's and higher degree levels.

### *2.4.2 The role of in-service education and training in teacher professional development*



According to Coldervin and Naidu (1989), Third World countries face major shortages of trained and qualified teachers at various levels. Although in their 1989 study, they argue that primary schools are the worst affected, they also point out that, depending on the situation in various subject areas, in some countries secondary schools are also affected. This is the situation in Zimbabwe and appears to have gone worse, given the prevailing economic hardships resulting in a serious wave of brain-drain. So many teachers and lecturers at all levels; primary, secondary, and tertiary have gone in thousands, leaving the country critically short of experienced professionals. With the country struggling under economic sanctions, there have also been serious shortages of curricular materials and physical facilities (Kwaira, 2006). In some cases, some of these professionals have chosen to go out as economic refugees, especially in neighbouring countries like South Africa and Botswana although others have ventured as far as the United Kingdom and the United States.

In several other countries, governments have had to reduce the level of publicly-supported education (Coldervin, 1980; Kinyanjui, 1987). Others have tried out various innovative solutions where most of the strategies have focused on the problem of certified teacher shortages stemming from the inability of conventional teachers' colleges to keep pace with demands (Zindi and Aucoin, 1995).

Coldervin and Naidu (1989) discuss two main dimensions of teacher shortage; quantitative and qualitative. On the one hand, the 'quantitative' dimension has to do with the numbers being introduced into the system at a given point in time (Thompson, 1984; Galda (1984). At the time of Coldervin and Naidu's study in 1989, it was observed that while teacher shortages derive primarily from continually high birth rates, they also resulted from government policies in various Third World countries where efforts were being made to achieve universal primary education. In Zimbabwe, this was actually the case soon after independence in the early 1980s. In recent times, another contributory factor in most countries has had to do with attempts to reduce higher teacher-pupil ratios (Kinyanjui, 1987; Tilson, 1987). Towards the close of the 1980s, data from Third World countries reflected ratios around 1 to 40+, or at least double those in industrialised countries [United Nations Educational Scientific and Cultural Organisation - (UNESCO, 1988)]. Although it is such a long time now, after this report on several countries, in Zimbabwe today (end of 2006) this is still the case; maybe even worse due to the prevailing economic hardships that have resulted in teachers leaving for greener pastures. On the other hand, the 'qualitative' dimension of teacher shortage has had a lot to do with the engagement of professionally untrained and/or academically unqualified or under-qualified personnel; with both aspects often being mutually extant. On a global basis, it has been estimated that between 20 and 30 per cent of the teachers in Third World countries are either professionally untrained or academically unqualified (UNESCO, 1988).

It is within the context of this background that it has been found necessary in many countries to have in-service teacher training playing a role in upgrading teachers already in service. This is the thinking that motivated this study, regarding the need to staff develop a specific group of teachers in order for them to teach Material Science (MS) at 'A' Level.

### *2.4.3 Models of in-service teacher education and training*

In the face of severe teacher shortages, several countries have tried to increase the output of their conventional training colleges (Lalor & Marrett, 1986). In some cases, lowering of entrance qualifications has gone together with the shortening of course duration for teacher certification. Some countries have recruited professionally untrained or academically unqualified teachers and pressed them into service before bringing them up to certification or qualification level through in-service distance education programmes (Guthrie, 1985). In Zimbabwe, this was the case in 1980 soon after independence when efforts were made to address the problem of teacher shortage resulting from the sudden influx of children, and in some cases even adults, into schools following the end of the war (Zvobgo, 1986).

Brophy and Dudley (1982) identify 53 Third World countries or projects using distance education for teacher training. According to the report by [United Nations Children's Education Fund – (UNICEF, 1986)], this number is believed to have gone up with more countries adopting and sustaining similar projects, especially given the cost effectiveness of that route. A typical example in Zimbabwe is the Zimbabwe Open University, which has grown considerably since 1987, to end up with the numerous intakes witnessed in various subject areas today. In such models, correspondence materials, broadcasting, and face-to-face tuition have been employed in the running of specific programmes. While in some cases only one of these three approaches has been used, in others, a combination of the three has been employed (Brophy & Dudley, 1983).



Distance education projects in teacher education range from large-scale programmes carried out in countries like the Ivory Coast, Tanzania, Sri Lanka, Kenya and Nigeria to medium-sized and smaller ones like those in Nepal, Malawi, Botswana, Lesotho, and Swaziland (Coldervin & Naidu, 1989; World Bank, 1987). In addition, many of the Third World distance teaching universities have in-service certificate programmes and good examples here are those in Cost Rica, Pakistan, Venezuela, Thailand and Colombia (Coldervin & Naidu, 1989; Kinyanjui, 1987). One can also include Zimbabwe among the countries in the last model.

Under this sub-section, the two main models identified for the professional development of teachers include; the conventional and distance education. These two models and their related attributes were discussed in order to explore specific lessons and experiences for the benefit of this study.

Distance education approaches to teaching were of particular interest. For example, the application of correspondence materials, broadcasting systems, and face-to-face tuition were useful alternatives and/or possibilities to consider for the purpose of this study. Even the approach used in the design and development of the instructional materials used in this study was to a great extent, influenced by materials used in distance education, especially the style of communication.

## 2.5 CURRENT ISSUES IN DESIGN AND TECHNOLOGY EDUCATION



The following questions guided the literature search under this section:

- What is Design and Technology education and what components comprise it within the Zimbabwean curriculum?
- What is the link or relationship between 'design' and 'technology' in education?

### *2.5.1 Components of design and technology within the Zimbabwean curriculum* *(The new orientation)*

The emergence of D&T education as an integral component of general education has become a significant international curriculum development of recent years (Baynes, Langdon & Myers, 1977; Yager, 1986; McCormick, Murphy, & Hennessy, 1994). Its distinctive curriculum features are technological literacy and capability. It also highlights the importance of 'knowledge in action', of 'doing' as well as 'understanding' (Zoller, 1990; McCormick, Murphy & Hennessy, 1994). In the Zimbabwean context, there has been adequate evidence indicating that the teaching of D&T as a component of general education is an emergent, rather than an established practice. Many questions stand to be addressed and the subject is still a grey area. In fact, it is on the basis of some of these questions that this study was aimed at bringing such challenges and possibilities (questions and possible answers) into focus.

In most countries, apart from the issue of D&T being part of the curriculum, little is known about students' learning and teachers' understanding of the subject and about what it means to become capable in it (Bowser, 1983; Meunier, 1980; Zoller, 1991; McCormick, Murphy & Hennessy, 1994). In the case of Zimbabwe, besides this common problem, there are important issues to be addressed in relation to the preparation of teachers, assessment of competence, and relationship between D&T and other curriculum elements, notably Science. In addition, there are significant policy issues and questions relating to the practice and rationale of curriculum change awaiting clarification. However, given the multiplicity of these issues, this study paid special attention to the first one; teacher preparation/professional development.

McCormick, Murphy and Hennessy (1994) assert that there is much uncertainty about how best to prepare teachers of D&T and the assessment of technological competence offers formidable challenges for researchers and policy makers alike. Attempts to develop and accommodate D&T education within different education systems would almost certainly repay study from a policy point of view. And, the relationship between D&T, and other subjects in the curriculum, especially Science, has now become a matter of academic and practical importance (McCormick, Murphy & Hennessy, 1994; Aikenhead, 1989; Bybee, 1987; Yager, 1985).



One of the most interesting findings in literature has been the fact that the form and content of D&T education differ among countries (Bowser, 1983; McCormick, 1990; Zoller, 1992). Justification also varies (McCormick, 1990). In some contexts, national economic concerns have impelled change. In others, the need to understand and control one of the most powerful influences on society today has been the primary motivation (McCormick, Murphy & Hennessy, 1994). Elsewhere, dissatisfaction with academicism and recognition of the importance of skilful performance (capability), have brought D&T into focus. In several countries, international agencies like UNESCO and the

Organization for Economic Co-Operation and Development (OECD) have supported and continue to support this curriculum innovation. According to McCormick, Murphy and Hennessy (1994), the work of many national and regional organisations concerned with D&T education is supplemented by the activities of the World Council of Associations for Technology Education (WOCATE). The central thrust of this innovation appears to be in the fact that D&T education is about doing and not simply about knowing. It is essentially about 'capability' and 'knowledge' in the context of action, rather than about understanding for its own sake (Rushby, 1987 and Jenkins, 1994). This is where such education is said to be about identifying a need, problem or opportunity, before to designing, implementing and evaluating a practical response which may be a system or an artefact within a social context. Theodore W. Adorno and Jurgen Habermas are among some of the most prominent social scientists who debate the importance of putting theoretical knowledge into practice. According to Holub (1991:33), for both scholars the objective meaning inherent in the social order cannot be separated from the demand for social emancipation. In this view practical questions are not juxtaposed with technical tasks, but rather are mutually implicated in the object: society as a totality.



Critical science 'allows its problems to be posed by its object,' and from this assertion, Holub (1991:33) concludes that the call for an immanent critique, shared by Adorno and Habermas, entails a unity of theory and practice. Although Holub's (1991) thesis of the works of Adorno and Habermas was mainly focused on the question of 'theory' or 'philosophy' relating to politics and society, the point remains the same when it comes to the present discussion on D&T; 'application of theoretical knowledge in solving practical problems'. Like Science-Technology-Environment-Society (STES) education, Design and Technology (D&T) education is political in the sense that it aims at the active involvement and responsible student-citizen action (Bowser, 1983; Zoller, 1992 & Holub, 1991). According to this orientation, D&T also deliberately aims to move students from unconscious automacity to conscious awareness of decisions and behaviours. In this case value-laden decisions must be made, and to take or make 'no decision' is to decide (Disessa, 1987; Williams, 1988). An interesting observation in this study was that a close analysis of the 2002 'A' Level D&T syllabus reflected most of these political tenets, especially those to do with the issue of citizenship. The nature of this syllabus, being a departure from the traditional, is such that teachers can no longer be the sole 'providers' of knowledge, through mediating textbooks to students as it used to be under the traditional Woodwork and Metalwork. Rather, they now should play, or are at least expected to play guiding and co-learning roles, be able to design an inquiry-oriented learning environment and shift from imparting knowledge to students to developing students' higher-order skills. In fact, such an emancipatory orientation is exactly what authorities like Meerkotter (2001) and Freire (1972) regard as being more progressive than the 'banking concept' of education.

In D&T theoretical knowledge is generated through various ways, for example, formal theory lessons/lectures, private reading in libraries and group discussions during brain storming. According to Jurgen Habermas, it is such knowledge that one has to put into practice in solving practical social problems if learning is to be meaningful and useful. Habermas is strongly opposed to learning or knowledge for its own sake (Holub, 1991).

In Zimbabwe, according to official policy, the advent of D&T has been motivated by economic concerns involving academic science in addition to a new approach emphasizing ability to integrate theoretically informed designs with skilful performance [Research Council of Zimbabwe (RCZ), 2002].



### *2.5.2 Linking theory and practice in design and technology* *(Lessons from Science and Technology)*

Under this sub-section, important lessons were drawn from Science regarding current practices and issues in practical work. According to Mafumiko and Ottevanger (2002), there is a strong conviction among teachers and researchers that hands-on activities have potential in developing various student abilities in Science and other related subjects like D&T. However, several investigations have recently proved that in many classrooms and laboratories there are serious discrepancies between the lofty goals expressed in the rhetoric of Science and Technology (S&T) education and the kinds of activities in which students engage (Ware, 1992). Mafumiko and Ottevanger (2002) agree with Ware (1992) when they argue that in some schools, especially in developing countries, there is no laboratory work at all. In others, there is hands-on practical work, but students follow a list of step-by-step instructions like technicians trying to reproduce expected results and struggling to get the right answers without sway. This also explains the criticisms levelled against the traditional approach to the teaching and learning of technical subjects, where a lot of practical work goes on with pupils/students following laid down procedures using recommended materials and tools, for example. The problem is that this is clearly a negation of creativity and emancipatory principles where learners are expected to make independent decisions in problem solving as propounded by Paulo Freire in his 'Pedagogy of the Oppressed' (Ornstein & Hunkins, 1998: 183). Mafumiko and Ottevanger (2002) also indicate that, few opportunities are given to students to discuss experimental results, to hypothesise and propose tests, to design and then actually carry out experiments.

The issue here is not simply the teaching and learning of skills. Of course either way, following the traditional or the D&T approach to the teaching and learning of technical subjects, we would still end up with the transmission of practical skills, particularly those relating to the production of artefacts. The issue is more rather to do with the nature of skills one would be aiming at promoting. If our aim is to promote or follow the progressive root usually associated with D&T, then we would worry about the question of rationality where one would engage in informed decision making during problem solving. According to Barrow (1984), this is what differentiates human beings from animals. While there have been cases of some animals performing certain tasks with better perfection than human beings, one would still not declare them rational from a philosophical point of view (Peters, 1973). This in itself suggests a distinction between instinct and rationality. To come back to the issue of teaching and learning, what we would like to see is not just the mere promotion of practical skills, but the development of skills being accompanied by thinking and informed or rational decision making.

Lazarowitz and Tamir (1994) put the blame for any shortfalls here on the nature of materials used in a given situation and maintain that the nature of classroom transactions is strongly dependent upon the curriculum materials employed. They believe that materials such as laboratory manuals, worksheets, or textbooks that include laboratory activities, largely determine the opportunities to learn afforded students. In this study, these observations by Lazarowitz and Tamir (1994) helped to demonstrate the critical role played by appropriate materials in the business of teaching and learning, at whatever level. Even the instructional materials developed for use with the serving teachers in this study were based on similar principles where they were designed for a specific purpose under specific terms. In this case the benefit or lesson was that, by design, these materials were somehow going to influence or promote special abilities in these teachers in order for them to end up being able to design their own materials for application with pupils in schools.

The level of resources, both in terms of quality and quantity is another crucial factor in achieving excellence in the teaching and learning of S&T (Mafumiko & Ottevanger, 2002). They (Mafumiko and Ottevanger) assert, "--- successful laboratory instruction requires adequate equipment, consumables, storage space, teaching literature and sufficient time". Unfortunately, experiences from many countries, especially in the developing world show that the low level of resources has been one of the main contributing factors to implementation problems of practical work in school S&T (Mafumiko & Ottevanger, 2002). This observation is also reinforced by Powell and Anderson (2002) who maintain that the resources required for successful laboratory instruction also include qualified, well motivated and confident staff or personnel; hence the need in this study, to staff develop the concerned serving teachers, being part of the relevant human resources.



However, Bekalo and Welford (1999) and Bradley (1999) present evidence on cases where teachers do not attempt to do practical work with pupils even when there are adequate classroom settings and reasonable resource levels. In such cases, the blame is placed squarely on lack of proper teacher preparation and professional development programmes with regard to practical work at both levels pre-service and in-service. Having learnt this much from S&T, one can now see why in this study the intention has been to link the Material Science (MS) course to the Machine Shop Practice (MSP) course. Such a relationship was actually necessitated by the need to put theoretical knowledge (MS) into practical application under MSP while at the same time being aware of one of the main areas of foci spelt out earlier in this study; 'enhance the competence of teachers in solving practical D&T problems where practical skills are guided by scientific knowledge and principles'.

## 2.6 CURRENT DEBATE ON EDUCATIONAL AIMS AND GOALS

Generally, the following questions guided the search for literature on this topic:

- What is the purpose of education?
- What is the purpose of teaching and learning?
- What is the relationship between education, teaching and learning in terms of aims and goals?
- Who determines the aims and goals of education in a given context?
- How do educational aims and goals influence teaching and learning?



While we can debate and differ as to the purpose or purposes of education, not many of us will disagree that education is purposeful. According to Ornstein and Hunkins (1998:268), we create curricula of various designs for both general and specific intentions. Indeed, those who develop curricula, teach curricula, or discuss the nature of schools and their curricula have some intent in mind. Ornstein and Hunkins (2004) also maintain that education is enacted for a reason. It may be emergent and random, as has been the case in most developing countries; nevertheless, it is an intentional activity created to either allow or enable students to attain specific understandings, skills, or attitudes or gain a receptivity to participate in the world; current and future, in particular ways, and even to design their own means of interactions (Cornbleth, 1990).

The fact that some of the intents in education are geared towards the immediate while others are geared towards the long term justifies and explains the place for objectives and aims in education. Respectively objectives are for the immediate and aims are for the long term (Bloom, (1987); Pratt, (1994). For example, while we may precisely indicate that after studying a unit covering a particular technical skill, a student would produce an artefact demonstrating an understanding of the behaviour of materials under specific conditions, the implication is that in future, the individual would apply such a skill in ways as yet unknown and unspecified. Moreover, as educationists we hope and assume, what the student does with this skill will demonstrate wise application of knowledge for personal and social benefit (Ornstein, 1985; Posner, 1992).

In times of rapid change such as we have today, in practically every country, society expects schools to help citizens adjust and this has implications for curriculum development as observed by Cornbleth (1990) in her discussion of 'Curriculum in Context'. She argues that curriculum construction is an ongoing social activity that is shaped by various contextual influences within and beyond the classroom, accomplished interactively and primarily by teachers and students. The curriculum becomes highly constructivistic in nature as explained by Oxford (1997) in a phenomenon she terms 'shape-shifting'; implying the quick adjustment of functions in situations of rapid change. In a related discussion Oxford (1997) refers to the concept of 'social constructivism' where development is guided by social events and trends. This is why in most cases society has often demanded that schools modify their programmes in order for learners to function more effectively (Bloom, (1987); Cornbleth, 1990). In most cases this has called for a revisit of the 'aims of education' in order for those aims and their objectives to remain relevant and appropriate in given contexts (Kyriacou, 1994). For example, in a problem solving situation, aims are the starting point for an ideal or inspirational vision of the good. In this respect, aims reflect value-laden judgements that help to guide the educational process. For the purpose of this study, the above was the orientation as I designed the instructional materials at the core. As educators, we are challenged to interpret the aims of education in relation to those of society (Bloom, (1987); Kyriacou, 1994). For me, it was the general aims of teacher education in Zimbabwe that I was concerned with. Several lessons were drawn from Doll (1996), who summarizes and interprets the following dimensions of what American aims of education should address:

(1) The *intellectual/cognitive* - Aims dealing with this dimension focus on the acquisition and comprehension of knowledge, problem-solving skills, and various levels of thinking.

(2) The *social-personal or affective* - This has to do with person to society, person-to-person, and person-to-self interactions. Aims targeting this dimension also subsume the emotional and psychological aspects of individuals and their adaptive abilities with regard to home, family, church, and local community.
(3) The *productive* – This centres on aspects of education, allowing and enabling the individual to function in the home, on the job, and as a member of the larger society.

In addition to the three dimensions noted by Doll (1996), Ornstein and Hunkins (1998:271) outline four others: (1) *physical* - dealing with the development and maintenance of strong and healthy bodies; (2) *aesthetics* - dealing with values and appreciation of the arts; (3) *moral* - dealing with values and norms that reflect appropriate behaviour; and (4) *spiritual* - dealing with the recognition and belief in the divine and the view of transcendence.



Given the task in this study, where the main activities were to design, develop, implement and evaluate a specimen program comprising a package of instructional resource materials, 'educational goals' were a burning issue. And, since such goals are generally statements of purpose with some outcome in mind, they guided the production of the intended instructional materials. According to Sowell (1996), these goals furnish answers to the following question: "What destination do you have in mind for learners as far as a particular curriculum or subject is concerned?" In this case, the destination intended for the concerned teachers was for them to end up being able to teach MS at 'A' Level through the D&T approach.

However, while goals suggest intended destinations, they do not specifically denote particular learning. Rather, goals address certain characteristics of the learner on attainment of the stated goals (Posner, 1992; Gronlund, 1985; Gronlund & Linn, 1990). For example, a curriculum that aims at developing learners into resourceful citizens, would most likely try to ensure that learners are skilled in the art of critical thinking, are responsible and have the capacity to work with people from all walks of life. Effectively the point is, when discussing or recommending goals in their generality, we do not pick on specific items for learning, but we highlight the qualities or characteristics that we expect in someone after learning several relative items, depending on the demands of a given context (Posner, 1992).

Having considered educational goals from a general perspective, it is then appropriate to relate the issue to the purpose of this study. Ornstein and Hunkins (1998:272) conclude:

> When speaking of goals, we are addressing curriculum goals or desired outcomes for students as a result of experiencing the curriculum. We are not addressing how teachers would instruct students to achieve these goals, although it is realized that instruction is related to the curriculum and that particular methods of instruction are selected mindful of the demands of certain contents and also the demands of students and their ability and interests.

This conclusion shows several threads leading to the principles and ideas employed in the design, development, implementation and evaluation of the instructional materials used in this study. During the preparatory investigations, traits of the ideas adapted from this conclusion could also be traced filtering into the various sections of the 2002 version of the 'A' Level D&T syllabus. Most of these were located within the aims and objectives, which in turn had a direct influence on the design and development of the instructional materials. The idea or decision to accommodate the needs, abilities, and interests of the concerned serving teachers was also taken from this conclusion.



To avoid the possible confusion noted in literature, one might want to differentiate between 'aims' and 'goals'. There seems to be a very thin line between these two. Ornstein and Hunkins (1998:272) maintain that;

> ---by analyzing a school's goals, we can determine the scope of its entire educational program. Goals, in contrast to aims, are not open statements. They are specific statements written so that those responsible for program creation can use them as guidelines to achieve particular purposes. Goals are derived from various aims and thus provide teachers and curriculum decision makers with broad statements of what they should accomplish in terms of student learning as a result of a particular subject or educational program.

What this seems to suggest is that the distinction between aims and goals of education is one of generality, where aims deal with the general process of education, such as 'developing problem-solving abilities' or 'creating technological literacy.' According to

Stenhouse (1975), no specific program or course in a particular school will attain all the aims that there might be. Several aspects of the curriculum are likely to address them. This appears to suggest that aims only become goals when they become more specific in relation to a particular school system and to a specific subject area. For example in this study, the broad aims from the 'A' Level syllabus only became manageable when they led to goals which were in turn reduced to objectives within the limits of the course-outline of the Material Science (MS) program. It was however necessary to take into account Ornstein and Hunkins' (1998) warning of the possible danger of confusing objectives with goals and aims.

In a school situation, one could perhaps argue that the creation of goals is an on-going activity in which educators continuously engage as they consider the philosophies of their schools and work to clarify their educational aims (Kemp, Morrison & Ross, 1994). In this study, it was not really the philosophy of a particular institution that was considered during development of the MS course, but that of D&T, both as an approach and as a discipline. After analyzing this philosophy, it was possible to come up with statements of objectives and outcomes or results expected to occur in consequence to the educational activities imbedded in the MS course as reflected in Figure 3.5 and Appendix 6. From this, it was then also possible to match students' learning and the goals generated for the course. Being constructivistic and developmental in nature, the whole process was characterised by a sense of continuity at almost every point. This is where this study could be said to have taken off from Dewey's (1964) comment on the issue of ends in education, referring to them as being continuous and ever shifting.



In Zimbabwe, we are currently going through a period that is characterized by rapid and continuous change. Most of these events and changes have been closely related to the serious political and economic challenges currently prevailing in the country. Therefore, one sees the relevance and validity of Dewey's (1964) argument, maintaining that the ends to which we strive are not really ends, but waypoints on a continuous journey. According to this observation, education is a journey where our intentions, however phrased, must inform the learner that the attainment of a waypoint enables him or her to proceed or advance to the next. This way of thinking is actually in agreement with the philosophy behind D&T, particularly in as far the concept of 'problem solving' is concerned. In this case, ends for a particular point are essentially the means for striving to yet another point, another destination, toward another intention. This is typical of the 'design process' as propounded by Mumford (1983); in line with Dewey's (1964:74) assertion that, " --- ends are in fact, literally endless, forever coming into existence as new activities occasion new consequences." Taking from this assertion, this is why, even after 'Implementation and Summative Evaluation,' the instructional design model underpinning this study, as reflected in Figure 2.2, shows the whole developmental process of the instructional materials going back, stage by stage up to 'Learner Analysis'.

## 2.7 TEACHING AND LEARNING WITHIN THE CONTEXT OF DESIGN AND TECHNOLOGY

Generally, the following questions guided the literature search under this section:

- What is the importance of instructional systems in teacher education and training?
- What pertinent issues surround the concept of teaching?
- What pertinent issues surround the concept of learning?
- What is the relationship between teaching and learning?



### *2.7.1 Pertinent issues surrounding the concept of 'teaching'*

According to Moore (1982), teaching is an activity in which one consciously accepts responsibility for the learning of another. In the case of formal education, the person who accepts responsibility for seeing that learning occurs is also responsible for the content of that learning. S/he is committed to the value judgment of the content and to ensure that what s/he passes on is worth passing on to another person. For example in D&T, this means whatever content one decides to pass on to the pupil should be useful enough to contribute to personal development immediately or some day in future. In this study, it was a course in MS that was to be offered to a group of serving teachers.

On the issue of ‘responsibility and value judgment,’ Moore (1982) emphasises the importance of considering teaching as an intentional matter where one intends to have someone else learning something which s/he (the teacher) is able to assess. For instance in D&T, when we engage pupils in an activity that we are able to assess at the end of the day, the whole exercise implies a certain level of commitment on our part. This is why it is important for one to make appropriate preparations; starting with the lesson plan, setting the exercise, organizing the marking scheme and then the actual marking. All these activities demonstrate how serious one would need to be when passing on knowledge to someone else. The issue of one being serious logically appears to imply the same individual being honest and sincere in his/her dealings as a professional. According to Moore (1982), this can only be possible where one is totally convinced that what s/he passes on is worthwhile; thereby, implying the element of ‘TRUTH’. Philosophically, ‘TRUTH’ becomes the underlying basis for all knowledge referred to as being worthwhile or useful. Nothing can be said to be useful or worthwhile, without being true (Barrow, 1984; Moore 1982).

### *2.7.2 Pertinent issues surrounding the concept of ‘learning’*



Having considered the concept of ‘teaching’, one must now consider ‘learning’. This is a many-sided phenomenon and different people have different preferences in methods of learning (Kemp, Morrison, & Ross, 1994). Investigations from literature during the early stages of this study showed that some people learn better from reading than from hearing, while others prefer the opposite. Just as there are many different phenomena to learn about, so too are there different processes of learning, resulting in different outcomes (Dahlgren, 1984). For example according to Hodgson (1984), there is learning of practical skills (by doing), through reading, from lectures (by listening), through writing (e.g. essays), and through problem solving. All these types of learning require different settings, approaches or methods, and even different instructional materials (Hounsell, 1984; Laurillard, 1984). For this study it was important to be aware of such differences in order to appropriately accommodate them within the design of the intended package of instruction materials. Cave (1986) believes D&T in many ways encompasses nearly all these types of learning, both in principle and in practice. For example, by its nature D&T

involves both theoretical and practical knowledge. For learning to be declared as having taken place there has to be adequate evidence in the form of change in behaviour and practice. This is when the effectiveness of a learning process is accounted for. The sequence of events in this study could be explained in a similar manner, as captured by the instructional design model in Figures 2.2.

Marton and Saljo (1984) contrast two main categories of learning. On the one hand, there is learning from materials that lack an internal order which might force one to worry about the issue of meaningfulness. In such cases the learning process involves pure memorization, either by constant repetition or by imposing some kind of meaningfulness, often through the use of mnemonic strategies (Marton & Saljo, 1984). On the other hand, a substantial amount of learning depends on understanding material which does have an internal structure that can be grasped (Svensson, 1984). In these cases the process of learning should aim at finding this structure in as deep a sense as possible (Svensson, 1984). This is a qualitatively different kind of learning, usually resulting in a different outcome, compared to the first approach. By nature this outcome represents a conception of a phenomenon in the real world. According to Saljo (1984), a conception can, in principle mean those very superficial characteristics of a phenomenon such as size, shape or colour and such a conception is taken to denote the 'nature' of an object or an event. From this position, Marton and Saljo (1984) assert that to 'understand' or 'accept' the colour or size of an object is a process totally different from understanding its nature. In the latter case, what is pivotal to grasp or understand is the relationship between a phenomenon and its context. This observation seems to suggest that external or concrete characteristics of a phenomenon do not alone provide a basis for understanding it. In this respect, everything is always a part of something larger or more inclusive and having a meaning beyond itself. This appears to comprise what we might call 'the context of understanding'. Meaningfulness is thus not an inherent property of nature or culture. According to Svensson (1984), it is imposed by human consciousness, which is itself evolving continually. Learning should then be regarded as that aspect of human life through which the environment, or the person her/himself, emerges with a higher degree of meaningfulness than before (Marton & Saljo, 1984:34). From this perspective it can then be said that knowledge is nothing but a series of occasional and provisional steps towards what is often described as an unreachable complete knowledge about reality.

From another angle and in another debate, Langford (1968:52) citing Hilgard's definition of 'learning' asserts that:

> Learning is the process by which an activity originates or is changed through reacting to an encountered situation, provided that the characteristics of the change in activity cannot be explained on the basis of native response tendencies, maturation, or temporary states of the organism (e.g., fatigue and drugs).

According to Langford (1968) this definition is borrowed from psychology where thinking is primarily based on behaviour and tends to be thought of in terms of bodily movements that can be observed. Langford (1968) goes further to maintain that, according to the behaviourist tradition in psychology stemming from J.B. Watson, psychology can only become scientific by confining itself to what can be directly observed. From this assertion, Langford sounds rather critical of the psychologist's definition of 'learning'. He argues that, the behaviour which is relevant to becoming a person cannot be thought of in such limited terms. It is more like the possibility of action, which is the practical possibility opened by the possession of what he terms 'a conceptual scheme'. This position is based on the premise that belief has a logical priority over action and certainly cannot be reduced to a mere disposition to act in a particular way. For example, in D&T it is important for us to note that before a pupil engages in a practical activity like arc welding or cutting with a hacksaw, there is a lot of thinking that goes on during the designing and planning stages of a particular practical activity or project. Therefore, Langford (1968) justifies the need to think more in terms of the acquisition of a belief rather than merely in terms of the modification of behaviour. This implies that, it is not good enough to think of learning as any permanent modification of behaviour resulting from prior experience. From this perspective, it appears sensible to say that unless the person whose beliefs or behaviour patterns have changed can be said to have achieved a success, it will not be correct to say that s/he has learnt anything.



Although Mussen, Conger and Kagan (1969) agree with Hilgard's definition of 'learning' as taken from Langford (1968), they also go further to argue that 'learning' represents the establishment of new relationships (bonds) or connections between units that were not previously associated. Learning refers to the establishment of new bonds, or strengthening of already existing associations that were weak. Mussen, Conger and Kagan (1969) argue that not all behaviour is learnt. Some response tendencies exist at birth and even during the prenatal period of life. Mussen, Conger and Kagan (1969) refer to evidence indicating that the papillary reflex (contracting of the pupil in the eye in response to light) has been observed even in premature infants.

Many other responses of infants; swallowing, opening and/or closing eyes, and even the act of crying, are not considered part of 'learning'. Mussen, Conger and Kagan (1969) are in agreement with Langford (1968) when they argue that 'learning' must be defined carefully to differentiate it from related concepts such as maturation, growth and development. They all restrict learning to a particular kind of change, related to the development of new associations. For the sake of debate, one could perhaps argue for a distinction between theoretical and practical skills. However, according to Narvaez (2000), this distinction is not as much as some of us would want to imagine. She describes a global and holistic conceptualization of the teaching and learning of skills, facts, and concepts within the context of D&T. According to this orientation, the fundamentals of teaching and learning are to an extent the same and universal. Narvaez (2000) proceeds to elaborate on this view when she maintains that, by putting theoretical knowledge into practical application as is normally the case in D&T, one could be said to be building bridges between theoretical ideas and practical skills. For example, taken either way, the evidence of learning having occurred in a given context is in the change of behaviour, either in conceptual or practical terms. These associations could for example, be between stimuli (sunshine and light), between responses (chew and swallow), or between stimuli and responses (female toilet sign – find another toilet). Taken this way, learning is a purely internal activity/event (Narvaez (2000). Happenings and activities in the brain might not be obvious to us, but generally, everything learned is stored specifically and individually, perhaps in a particular brain cell or maybe in the form of a unique pattern of the brain-cell activity (Langford, 1968). This means, learning is stored in the brain indefinitely, even if it is never acted out in behavioural terms. Similarly, earlier forms of learning continue to exist in the brain even though they might have been surpassed in behaviour by more efficient or sophisticated versions. For example in Metal Technology and Design, if the pupil had learnt how to use the manual hacksaw, the know-how will remain in the brain although s/he might later, be using the power hacksaw for most cutting operations. According to constructivistic thinking, the ideal is to have new information linked to old information. Even in the learning of skills, the same sense applies when one perfects old skills through practice and improvement in dexterity.

Good and Brophy (1977) agree with Langford (1968) on the issue of 'learning', when they maintain that the key to learning is in the attainment of new associations, not acting out these associations in behaviour or performance. This appears to imply that we know many things that we act out and learning is usually defined so as to include those changes that result from experience. From this argument, purely physical processes such as growth and the behavioural changes occurring with maturation are excluded as already observed. Much learning occurs in connection with growth and maturation, but any changes in behaviour or functioning that come about solely because of biological maturation are not considered part of learning. Changes that occur in connection with growth, development, and maturation stimulate learning and influence the forms it takes, but they are not the same as learning itself (Good & Brophy, 1977).



### *2.7.3 The relationship between teaching and learning*

After defining 'teaching' and 'learning' separately, there is now need to relate them and identify the common threads between them. In fact, to look for a relationship between these terms implies seeking a relationship between the teacher and the learner in the process of teaching and learning (Brewer, 1985). Understanding this relationship was very important since it gave insights into the nature of communication that had to be promoted within the instructional materials.

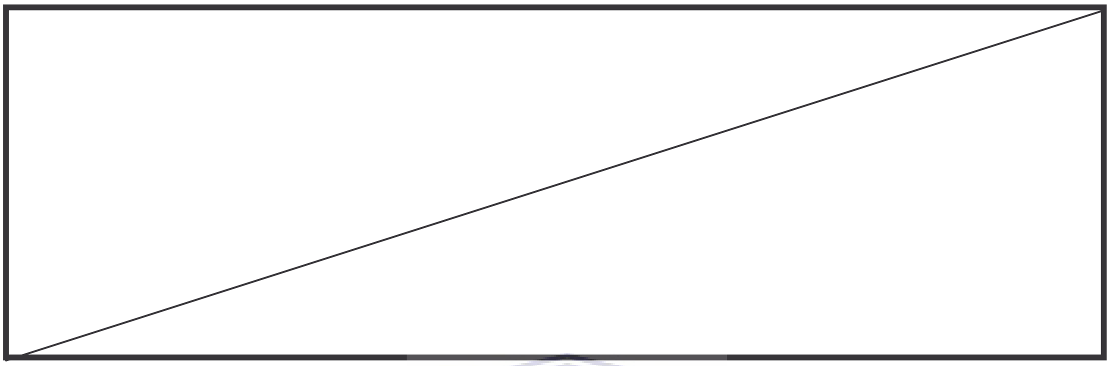
According to Beard and Hartley (1984) and McKeachie (1986), teaching may be regarded as providing opportunities for students/pupils to learn. And, the provision of opportunities in whatever context suggests and implies the presence of those assumed to have the capacity to take advantages of the opportunities (Cohen, 1981; Marsh, 1982). This is where the learner comes in, making teaching an interactive process that is also intentional in nature as an activity, as already implied under Sub-section 2.7.1. Whatever the nature of knowledge; be it skills based or conceptually founded, the bottom line remains the same regarding the question of 'provision' being followed by the 'taking' of provided opportunities. Effectively this means the relationship between teaching and learning remains basically the same in principle. Of course, beyond this point there could be variations regarding this relationship. In this study, such insights motivated careful thought about what activities to build into the instructional materials. There was need to have an idea of the nature of opportunities for learning that individual activities would allow for. However, one had to take note of Brewer's (1985) and Brown and Atkins' (1988) warning and observation that, 'learners may not always learn what we might intend to have them learning and they may, sometimes alas, also learn notions which we may not intend them to learn'. This is why it was necessary and important to determine the effect of the Material Science (MS) course on the perceptions and understandings of teachers, regarding content and instructional practice in D&T. After the teachers had undergone the course, there was need to check on the achievements of the whole teaching and learning process. It was neither safe nor wise just to assume and take for granted that the intended learning had taken place according to plan. From a constructivistic point of view, one cannot always expect learning to occur as planned. In reality alternatives are always possible (Wertsch, 1985). This was the guiding principle in this study.

Following Brown and Atkins' (1988) arguments on teaching and learning, in D&T the sky appears to be the limit when it comes to content and learning activities. Such content comprises facts, concepts, theories, procedures, skills (both, theoretical and practical or technical), ideas and values. Our goals in teaching and therefore, for the learning of the pupils/students we teach include gains in knowledge and skills; the deepening of understanding; the development of problem-solving skills or abilities and changes in perceptions, attitudes, values and behaviour. Of course, these goals may not be all that obvious to our pupils/students considering their level of thinking, which might not always be that critical.

Since teaching is an intentional activity concerned with learning, it therefore follows that it is worthwhile for us to take time thinking and articulating our intentions in teaching and/or communicating particular topics or aspects to our pupils/students (Brown & Atkins, 1988). Following this, it is also sensible to spend time checking on whether our intentions are realistic and are indeed realized.

Relating the teacher and the learner also means considering their levels of participation within the enterprise of teaching and learning. To illustrate the point here, it has been necessary for us to borrow Brown and Atkins' (1988) ideas on teaching and learning. They place various teaching strategies on a continuum as illustrated in Figure 2.1. This figure has been slightly modified in order to suit the purpose of this study. For details pertaining to the nature of modifications, one could perhaps check on the format of the whole continuum and the items therein. On items to do with approach, in place of 'research supervision', we had 'design and research supervision' and in place of 'lab work' we ended up with 'workshop activities'. Instead of the 6 approaches outlined in the original continuum by Brown and Atkins (1988), the modified version had only 5 following the elimination of 'self instructional systems' which was assumed to be accommodated in 'private study'. Another area of modification was in the levels involved, where instead of referring to the 'lecturer and student relationship' as in the original continuum, the present continuum relates the teacher and the pupil. While Brown and Atkins (1988) focussed on teaching and learning at tertiary levels (particularly university level) in this study, the focus was on teaching and learning in schools since the teachers involved were expected to go and teach at 'A' Level on completion of their studies. At one extreme, is the lecture method in which pupil contribution or participation is usually minimal and at the other, is private study where there is very little active participation and control by the teacher. Examining this continuum closely, it should be pointed out that, even at each extreme end, there is some contribution and/or participation by both; the teacher and the pupil. Hence in lessons, pupils may choose what notes to take, whether to ask questions and sometimes, even disrupt the direction of the lesson. On the other hand, the pupil's private study is likely to be influenced by the suggestions made by the teacher, the materials and tasks that s/he provides together with the texts in the library. In D&T, a good example of this is a situation where we engage pupils in design activities and expect or advise them to go and investigate in libraries and only come back to us for consultation on an individual basis (Lindblad, 1990; Liao, 1994).

**Teacher contribution and**
**Participation** (control)



*Lesson *Small group Teaching *Design & Research Supervision *Workshop activities *Private study

**Pupil contribution and Participation** (control)

**Figure 2.1** A continuum of teaching approaches (Adopted from Brown & Atkins, 1988)



The lessons and insights from here were very useful in the decisions that were taken regarding approach to the teaching and learning relationships in this study. For example, much of the teaching was mainly among the serving teachers themselves. This was meant to instil in teachers the idea of having pupils being more responsible for their learning. After their education and training, teachers were expected to promote such a perspective in schools by implementing the same approach in their teaching. In this study teachers were also engaged in a lot of private study especially during research and investigations for the various workshop activities where they were even expected to evaluate their own work. On the whole, this was mainly in line with the third area of foci which had to do with ‘increased understanding of how to teach pupils to solve technical problems in D&T by putting theoretical knowledge into practical application’. From a constructivistic point of view, learners were expected to come up with their own versions of solutions to particular problems since the belief was that of no single solution to a given problem (Lewis, 1993; Lewis, 1994). This view has been strongly supported by Confrey (1990) and Bruner (1986), after their findings in relation to the 'study of mathematics in practical application' where they discovered that pupils came up with a variety of solutions to given problems, outside the teacher's expectations. Likewise, in this study I also expected the serving teachers who were involved, to come up ideas and suggestions outside and beyond my expectations at various levels during the course.

## 2.8 INSTRUCTIONAL SYSTEMS IN TEACHER EDUCATION AND TRAINING

The following questions guided the literature search under this section:

- How do instructional systems fit into teacher education and training?
- How does the concept of 'systems thinking' affect decision making in teacher education and training?
- What is the importance of systems thinking in problem solving within the context of teacher education and training?



### *2.8.1 Systems thinking and decision making*

Inclusion of this topic was motivated by several factors, chief among which were those relating to the fact that this whole study was about the design and development of a system of instructional materials. The system was intended to result in a process of teaching and learning, after which there would be an evaluation to determine the outcome of the whole process in terms of effectiveness on the perceptions, understandings and knowledge of teachers, regarding specific concepts in Material Science (MS) and instructional practice in Design and Technology (D&T). The whole process of instruction, from the design, development and implementation of the instructional materials, right up to the evaluation of the materials, called for a lot of decision making. For example, choices had to be made regarding the selection of content items to include in the course outline and the respective methods of teaching at various levels. This justified the inclusion of this topic since there was need to think in systems terms. By analogy, such a system could be likened to a piece of machinery that would function according to one's intention in the design.

To a large extent a system exists because someone has defined it as such (Romiszowski, 1981a.). In the case of the instructional materials at the core of this study, the challenge was to devise a system of instruction that would meet specific requirements in terms of design. According to Romiszowski (1999), some systems, like machines define themselves in the sense that their functions would be clear enough from the mere look. Romiszowski (1981b.) gives a bicycle as a typical example of a system of transport whose function is clear from the look. Some systems are far more complex than that and their functions are usually not all that obvious (Dick, 1987; Dick & Reiser, 1989).

For practical purposes in teacher education and training, a system exists because we have chosen to consider it as such. This means we must draw the boundary that limits the extent and scope of the system, thus defining the components, or sub-systems that comprise our system of interest. This is what Romiszowski (1981a. & 1982) has defined as 'systems thinking' where it is important for one to identify the principal connections between a particular system and its environment, the inputs from the environment to the system and the outputs from the system to its environment. Explaining this further, Romiszowski (1981a.:6) introduces the concept of the 'black box' when he argues: "A system is a little black box, of which we don't unlock the locks, but find out what it's all about, by what goes in and what comes out". The first step in systems analysis is to define the system of interest, its boundaries and the chief inputs across these boundaries. Quantifying these inputs and outputs defines the purposes and to some extent the efficiency of the system (Dick, 1987; Dick & Reiser, 1989).



Things may be more complex than expected. There may be various sub-systems, each with its own objectives contributing to the overall objectives (Dick, 1987; Dick & Reiser, 1989). In addition, there may be alternatives for one to choose from. A successfully designed system involving human beings should, apart from achieving its objectives, also be acceptable to the majority of the potential clients or users (Romiszowski, 1999). This is certainly a point to consider in designing educational or training systems and this study was a typical example of such an activity! However, as a general rule Romiszowski (1981a) suggests that we should not open the 'black box' (breaking into the system every time there is a problem) unless this proves to be really necessary. Perhaps, the challenge here is to tell or determine the situation when it becomes necessary! From a lay or novice instructional designer's point of view, and given the analogy of the 'black box' as borrowed from aircraft technology, it may be necessary to explain this by equating it to the everyday operations of an aircraft. Under normal circumstances, pilots and even maintenance technicians do not have to worry about the operations of the black box. As we know, it is usually and only after an (accident/plane crash) that investigators open the black box to determine the cause of failure in the whole system. Similarly, this also appears to be the case in education and training systems. Once we have defined the outputs and know the capability of our system, we usually have some means of controlling the output from outside the black box or system. Romiszowski (1984) gives the example of a listener who may control the waveband, tone and volume of a radio without the need for any knowledge about how a radio functions in technical terms. A ministry of education may (to a point) control the output of a school system by manipulating output criteria, input resources and capacity without detailed knowledge of the instructional processes going on in schools (Romiszowski, 1981a.). On the other hand, the same goes for a teacher/lecturer who may (to a point) control the learning of a pupil/student by observing the outputs (new capabilities or behaviours) and manipulating the inputs (type of information, type of task, frequency and repetition of behaviour and duration of practice among other factors) without any detailed knowledge of the internal learning processes, going on inside the mental faculties of the pupil/student. In all these cases, one is applying control by feedback. It is only when this mode of control fails that we have a system malfunction, which might possibly justify the cost, time and effort of a detailed systems analysis.

When normal controls fail, officials in any ministry of education would become interested in the details pertaining to curriculum design, teacher training, teaching methods and other aspects of the process (Romiszowski, 1981b.). Similarly, only when the teacher has exhausted his/her own resourcefulness in adapting instruction for the benefit of pupils; guiding, explaining, demonstrating, motivating among other possible solutions, should s/he look for systems malfunction in the pupils/students and for this s/he may need the expert help of the school psychologist. At least, this is what has been happening in Zimbabwe. The Schools' Psychological Services have only been invited in extreme cases where 'special classes' have been created in some schools for such purposes.

Elaborating on the concept and analogy of the 'black box' in relation to the complexities of an education system, another way of looking at it is to note that, in as much as the 'black box' is sophisticated and complex, an education system is equally demanding in terms of design. Just as the design of the black box is time consuming, the same goes for an education system. Both are long-term and expensive. We cannot afford to dismantle and re-design either of these systems every time there is a problem regarding output. Considering the task in education, this view suggests curriculum designers taking a lot of care when designing and deciding on what goes into the system. This is the kind of thinking I held as I designed and decided upon what went into the instructional materials at the core of this study. While modifications were expected after formative evaluation, those modifications were not going to amount to an overhaul and/or a re-design of the whole system from the foundation. Although summative evaluation was expected to be more extensive and far reaching, possibly even amounting to opening up the black box; a complete overhaul of the whole instructional system was still not going to be all that obvious. It all depended on the outcome of the evaluation.



However, Romiszowski's (1981a.) views on this issue (systems thinking and decision making) have been fiercely challenged by constructivists like Confrey (1990) and Resnick, Berg and Eisenberg (2000) who express curiosity to see what lies within and beyond the black boxes. They suggest that the teacher should be in a position to explain the thinking processes leading to specific patterns of behaviours exhibited by pupils/students. Their argument is that this might lead to a better understanding of the problems faced by learners in their learning. This is the view that was more attractive and appealing in this study although it was not all that easy to determine how far one would go along that path. For example, in some cases, the main problem was the issue of resources where one would not have the capacity to deal with all the problems encountered by learners, no matter how far they might have broken into the black box. Some of these issues were considered beyond the teacher's control. At best in some cases, teachers are only able to make recommendations where possible.

### *2.8.2 Dealing with problems in systems terms*

Problems, like systems, exist in the beholder, where one expresses dissatisfaction with things as they are. One person's problem may be another's panacea or solution (Romiszowski, 1981a.). From this assertion, the argument appears to be that real problems are those that generate enough dissatisfaction to justify something being done about them. Someone should be sufficiently dissatisfied with 'what is' in order to pay the cost of achieving 'what should be' (Gagne, 1985). This cost may simply be the inconvenience caused by a simple change, or it may be a complex of real costs: time, money and other resources required to develop and implement a solution. The amount one is prepared to pay is a measure of the worth of a successful solution. One may sometimes be able to objectively calculate this worth, from the value of changing the 'what is' into 'what should be'. In industry and commerce, productivity increases, and reduction in waste or overtime or turnover can all be quantified to establish the worth of a successful solution (Gagne, 1985). In general education, it is somewhat more difficult to establish the worth of an innovation, but this is no excuse for not trying. According to Branson and Graw (1987) this could be done by; firstly, identifying the system which best defines the problem in input/output terms and secondly, defining the problem as a discrepancy between the current state of the system and the desired state. They then suggest that, if one experiences difficulties in doing this, they are probably looking at the wrong system.



In this study, there was an existing problematic system that required a counteracting system in the form of a solution to the existing problem. The problem where teachers were not performing as expected required a systematic form of solution, hence the need to deal with it in systems terms. In this case, the task was to come up with an effective system of instruction that would enable the professional development of teachers. From a systems point of view, being global and holistic as already noted elsewhere in this literature search and following the production and implementation of the instructional materials, there was a need to determine the effectiveness of the materials through evaluation case studies in a systematic manner. That system was adequately accommodated in the instructional design model first introduced in Chapter 1 under Figures 1.1. As already noted, that model was at the heart of this study from a systems point of view. From the way the study was conducted as presented in Figure 1.1, subsequently revisited in figures 2.2 and 5.1, the whole study (problem) appears to have been approached in a systematic manner.

### *2.8.3 Instructional systems guiding teacher preparation and development*

Since the business of teaching and learning is so serious, one cannot over-emphasize the importance of instructional systems in teacher preparation. According to Gagne and Glaser (1986), there is an increasing move to apply cognitive psychology to instructional systems. This places a lot of emphasis on learner analysis, cognitive strategies, motivational strategies, and information presentation strategies. As already observed in this study, John Keller's model of motivational design (as highlighted in Gagne, Briggs & Wager, 1992), stresses the need to look not only at what we teach, but how we teach it so as to make learning more meaningful. This is exactly what teachers should be aware of, through appropriately designed instructional systems. According to Wager, Applefield, Earle and Depsey, (1990), methods of instructional design should go as far as possible in defining the learning purpose of each design step. This implies that details of instruction, however arrived at, will have a sound foundation in research and theory.



Instruction is a human undertaking whose purpose is to help people learn and, Gagne and Merrill (1990) reinforce this point by maintaining that instruction is a set of events that affect learners in such a way that learning is promoted. One might ask, 'Why do we speak of instruction rather than teaching? According to Gagne and Merrill (1990), it is because we wish to describe all of the events that may have a direct effect on the learning of an individual. Instruction may include events generated by a passage in a book, by a picture, or by a combination of these media, among other things where the teacher may play an essential role in the management of any of these events. Instruction must be planned if it is to be effective (Wiles, 2005).

## 2.9 THE DESIGN AND PRODUCTION OF INSTRUCTIONAL MATERIALS FOR THE PROFESSIONAL DEVELOPMENT OF TEACHERS

Generally, the following questions guided the literature search under this section:

- What theories or principles are available for the design and production of instructional materials for the professional development of teachers?
- What theories or principles have been tried elsewhere in the design and production of instructional materials for the professional development of teachers?
- What is the relationship between taxonomies and educational objectives in the design and production of instructional materials?

### *2.9.1 The need for instructional materials in the professional development of teachers*



As already alluded to under Section 1.1 in Chapter 1, educational reforms and innovations are usually associated with the use of new materials (Klein, 1980; Sevigny, 1987; Powell & Anderson, 2002). The general view among these sources is that, without the appropriate materials to support teaching and learning, not much might be achieved from given reforms and innovations. This is why, for some educationists, it is pointless to discuss educational reforms without referring to curriculum materials (Powell & Anderson, 2002:107-136). According to Klein (1985) such materials are an important vehicle of educational reform. In Zimbabwe, the nature of reforms has meant the introduction of new syllabi that demand appropriate instructional materials at various levels. A typical example in this case was the course in MS designed for serving teachers in the Department of Technical Education at the University of Zimbabwe.

Romiszowski (1999) identifies Robert Gagne as one the most influential of recent writers in education who have taken ideas from the behaviourist camp, the gestalt camp, the humanist camp and more recently, from the cybernetics camp and combined them into one theoretical approach to the design of instruction. Exemplifying the neo-behaviourist view-point in most of his works, Robert Gagne has produced books and dissertations dating as far back as 1965 and spanning into the 80s, expounding his views on learning and instruction. A study of his works reveals a gradual, but constant growth in his ideas on learning and instruction. However, after a close examination of these works, Romiszowski (1999) has noticed distinct characteristics remaining throughout and distinguishing him (Gagne, 1985) from the strict behaviourist on several counts. In the final analysis, several behaviourist concepts have become fused into a complex and complete theory of instruction which has also become a good example of an effective eclectic theory in the production of instructional materials (Romiszowski, 1999; Klein, 1994). Since Gagne's (1985) theory has been just an example among many, there have been problems resulting from a divergence of opinions among practitioners as to the aims of education, communication difficulties, sloppy concepts and misunderstood terminology. Several attempts have been made to remedy this situation by the development of techniques and tools that would standardize procedures and terminologies. The earliest and perhaps still the most used tool is the taxonomy, which is a classification system that standardizes nomenclature, classifies examples unambiguously and establishes a hierarchy of interrelationships between groups of ideas and concepts (Klein, 1986). The application of taxonomies in education has been effectively described and demonstrated by Benjamin Bloom, whose list of taxonomies has become an effective model to guide the production of instructional materials in many education systems (Bloom, 1956 in Romiszowski, 1981a. and in Ornstein & Hunkins, 1998). This study benefited from Bloom's experiences taken from Romiszowski's instructional design approach.

### 2.9.2 *Taxonomy levels in instructional systems under design and technology*

When making curricular decisions, especially those relating to the generation of objectives, we as educators ideally need to consider specific domains of learning; the cognitive, the affective, and the psychomotor being typical examples. Several well-known classifications of learning have been established over the years, leading to an equally wide variety of taxonomies (Glaser, 1984; Ornstein & Hunkins, 1998).

**Focus on the cognitive domain**

Of all the classifications of realms of objectives, Benjamin Bloom's Taxonomy of Educational Objectives; the Cognitive Domain is perhaps the most familiar and certainly has the greatest influence on the formation of objectives (Ornstein & Hunkins, 2004). Bloom's (1956) taxonomy categorizes cognitive learning into six divisions, explained as follows:

1. Knowledge: This level includes objectives that are related to knowledge of (1) specifics, such as facts and terminology; (2) ways and means of dealing with specifics, such as conventions, trends and sequences, classifications and categories, criteria and methodology; and (3) universals and abstractions, such as principles, generalizations, theories, and structures. A good example here is a case in Material Science (MS) where a student might identify and name the most active or reactive metallic element in the periodic table.
2. Comprehension: This level involves objectives that deal with (1) translation, (2) interpretation, and (3) extrapolation of information. For example, from a verbal description of a problem situation a student in Design and Technology (D&T) should able to propose realistic possible solutions.
3. Application: This level includes objectives that are related to using abstractions in particular situations. For example, in MS the learner would be able to predict the effect of heat on a thermoplastic container.

4. Analysis: This level includes objectives that relate to the breaking of a whole into parts and distinguishing (1) elements, (2) relationships, and (3) organizational principles. For example, in D&T when given a design brief, the student should be able to distinguish problems from possible solutions.
5. Synthesis: This level includes objectives that relate to putting parts together in a new form such as (1) a unique communication, (2) a plan for operation, or (3) a set of abstract relations. For example, confronted with a report on material failure in a mechanism, the student should be able to propose ways of testing various hypotheses.
6. Evaluation: This is the highest level in the cognitive taxonomy in terms of complexity. Objectives at this level have to do with judgments relating to (1) internal evidence or logical consistency and (2) external evidence or consistency with facts developed elsewhere. For example, the student appraises fallacies in an argument.

**Focus on the affective domain**



Krathwohl (1964) presents a taxonomy of objectives comprising the following five major categories, in the affective domain:

1. Receiving: Objectives at this level refer to the learner's sensitivity to the existence of stimuli. This includes (1) awareness, (2) willingness to receive, and (3) selected attention. For example, after studying various African cultures, the learner develops an awareness of aesthetic factors in dress, furnishings, and architecture. Obviously, this influences one's way of thinking when it comes to issues like the choice of materials for various applications in problem solving under D&T.
2. Responding: Objectives at this level refer to the learner's active attention to stimuli such as (1) acquiescence, (2) willing responses, and (3) feeling of satisfaction. For example in D&T, the learner would display an interest to engage in the brain storming of relevant issues during problem solving and actively participate in research.

3. Valuing: Objectives at this level refer to the learner's beliefs and attitudes of worth. They are addressed in the form of (1) acceptance, (2) preference, and (3) commitment. For example, the student would take a viewpoint on the relevance of science and technology in society.
4. Organization: Objectives at this level refer to internalization of values and beliefs involving (1) conceptualization of values and (2) organization of a value system. For example, the learner would make judgments about his or her responsibilities in the fight against environmental degradation. In D&T, this would perhaps go as far as influencing one's choice of materials and mechanisms in problem solving, bearing in mind that some options are not environmental friendly while others are.
5. Characterization: This is the highest level of internalization in this taxonomy. Objectives at this level relate to behaviour that reflects (1) a generalized set of values and (2) a characterization or philosophy of life. For example, the student would develop an awareness of the importance of cooperation in nation building based on social and ethical principles. Tenets of this level of the taxonomy have had an impression on the instructional materials at the centre of this study, especially where group activities have been involved, originating from the 'A' Level D&T syllabus. Most of these tenets have been in line with 'social constructivism' as propounded by Black and Ammon (1992) in their presentation of the 'role of social interaction in teacher education'. It is also from this position that they also proceed to propose a developmental-constructivist approach to teacher education; an approach that uses Piagetian developmental theory and research as core knowledge for the preparation of teachers for their roles in schools. A possible question here for any critic could be, 'Why refer to the Piagetian developmental theory in this case when Piaget himself is not regarded as a social constructivist?' The argument is that, while Piaget was not a social constructivist, it is Black and Ammon (1992) who adapt Piaget's developmental theory in their constructivistic approach to teacher education and training. In this case, they take advantage of Piaget's theory just like one would take advantage of any tool to solve a given problem in a creative manner. They propose a model program synthesizing three general areas of study: developmental theory, teaching

methods, and field work where social interaction is used as a resource for conceptual development. This position regarding the model is strongly supported by Schifter and Simon (1992) who maintain that the negotiation of shared meanings within social interaction often provides a source for conceptual development. However, according to Richardson (1994) this program emphasizes social interaction much more than Piaget did.

Thoughts from this domain were particularly instrumental in allowing the social dimension overtly to enter and influence the constructivist foundation upon which this study was built.

**Focus on the psychomotor domain**

The psychomotor domain has received much less emphasis than either the cognitive or affective domains. Fewer educationists have worked on delineating it (Ornstein & Hunkins, 2004:286). The most outstanding of the recognized few has been Harrow (1972), whose psychomotor taxonomy comprises the following categories:



1. Fundamental movements: Objectives in this category address behaviour related to (1) walking, (2) running, (3) jumping, (4) pushing, (5) pulling, and (6) manipulating. A typical example could be the learner being able to jump over a 1-metre hurdle (Ornstein & Hunkins, 2004). On the other hand, in D&T 'pushing' and 'pulling' could be part of the skills development in preparation for the dexterity usually associated with the manipulation of tools like the jackplane in the preparation of timber and the manual hacksaw where 'pulling' and 'pushing' are typical movements associated with the cutting action. In practice, these movements are special abilities to be developed in pupils through appropriate teaching methods. While they might appear simple, some of these skills usually take years to master and require a lot of practice, especially where one considers the issue of safety in the use of dangerous cutting tools and materials.

2. Perceptual abilities: Objectives under this division address; (1) kinaesthetic, (2) visual, (3) auditory, (4) tactile, and (5) coordination abilities. This is where for example; the student in D&T would be able to categorize by type a group of materials, say metals,

polymers and ceramics. In Material Science (MS), this is very important. These are some of the abilities that had to be promoted within the scope of this study as enshrined in the MS course, given the purpose of the study.

3. Physical abilities: Objectives included at this level are related to (1) endurance, (2) strength, (3) flexibility, (4) agility, (5) reaction-response time, and (6) dexterity. Here the learner would for example, be able to manipulate a screw-driver to safely drive screws in order to hold components together. This level is very closely related to the first one, regarding the issue of dexterity, which is a typical quality in D&T.

4. Skilled movements: Objectives at this level of the domain are concerned with (1) games, (2) sports, (3) dances, and (4) the arts. For example, the learner would be able to strike a cricket ball correctly and score the highest points at a given moment. Although these skills appear not directly related to much about the technical skills promoted in D&T, the activities associated with these objectives are of particular interest. The sport persons, dancers and artists involved, usually need the services of the designer/technologist in solving specific technical problems (especially those relating to equipment/facility development). This is where those designers and technologists educated through D&T come in.



5. Non-discursive communication: Objectives at this final level of the taxonomy relate to expressive movements through (1) posture, (2) gestures, (3) facial expressions, and (4) creative movements. The student would, for example be able to create his or her own movement sequence and perform it to music, say Zimbabwean traditional music.

All the taxonomies outlined and described here were found generally useful in this study for developing educational objectives and for grouping sets of objectives, particularly during the design and production of the instructional materials. However, as work on the instructional materials progressed; there was need to consult Wittrock and Baker (1991) who have always warned of the problem of educators experiencing difficulties in making decisions and identifying objectives between adjacent categories. For the instructional materials in this study, the only way to keep on the safe side was to make sure the objectives were clearly stated from the start (see the course outline in Figure 3.5 and Appendix 6). By carefully and continuously reflecting on the objectives, I found these taxonomies valuable in creating and improving them. The design and development of the resource materials where the main component comprised of the module supported by its related tests, activities and exercises, was based on a sequence adopted from that recommended by Ornstein and Hunkins (1998), suggesting the following: Philosophy --- Aims --- Goals, and --- Objectives. In addition to this came the content. This sequence was vivid from the very foundation of the resource materials, especially in the course-outline as shown in Figure 3.5 and Appendix 6. Proceeding from the most general statements to the more specific, as reflected in this sequence, several levels or types of objectives were denoted beginning with those indicating general outcomes relating to specific areas of MS right up to those specific outcomes resulting from classroom, laboratory and/or workshop instruction.

On the whole, most of the thoughts generated from the foregoing discussion under this section on the various taxonomy levels, in conjunction with their respective domains influenced this study in several ways, especially from a methodological point of view. The developmental approach to research used in this study had its origins here, together with the associated constructivist frameworks within the instructional system represented by the instructional design model, starting from Figure 1.1 and progressing to Figure 2.2.



## 2.10 THE IMPORTANCE OF INSTRUCTIONAL MATERIALS IN TEACHER PROFESSIONAL DEVELOPMENT

The following questions guided the search for literature under this section:

- From the studies that have been conducted elsewhere on this topic, which ones could be of interest for the purpose of this study?

- Given the Zimbabwean situation, what lessons could be learnt from experiences elsewhere regarding the importance of instructional materials in the education and training of teachers?

Tilya and Voogt (2002) maintain that the development and application of curriculum materials facilitate curriculum change, as long as the practice of the classroom is taken into account. In Tanzania, student and teacher support materials were developed and formatively evaluated during workshops and seminars.

To help students concentrate on the activities as well as on learning, Tilya and Voogt (2002) were guided by the following design principles: problem solving, life application, knowledge integration and transfer, hands-on experimentation, no theory specification, minimal laboratory instruction, and group learning. Under each principle, specific issues were taken into account, for example, the interests of particular groups of learners. Elsewhere the issue of 'NO THEORY SPECIFICATION' has been controversial, raising fundamental questions. Therefore, it has been found necessary to explain and clarify the position in this study. In this case, the phrase refers to the situation where pupils are not restricted and confined within the boundaries of a predetermined theory, given as a prescription. Effectively, they are left free to choose their own path in order to come up with their own theory or theories, thereby fulfilling one of the most cardinal principles of constructivism, incidentally in agreement with one of the principles enshrined in D&T. 'Coming up with a theory' refers to cases where pupils/students come up with an informed choice of a theory from a collection of existing theories for application in a given context. This phrase also refers to a situation where learners organize their thinking in a systematic manner resulting in a new way of thinking, amounting to a 'theory'.

On teacher support materials, Tilya and Voogt (2002) were influenced by Van den Akker (1999) who, for implementation purposes, identifies four specific areas to focus upon. These include; lesson preparation, subject content, pedagogy and learning effects (Van den Akker, 1999). Voogt (1993) observed that teachers who used carefully designed teacher support materials for lesson preparation were also able to carry out successful activity based learning with students/pupils. Similar views are expressed by Ottevanger

(2001) from his work in Namibia, where he describes curriculum materials and their application as organizing elements in in-service scenarios, and subsequently in classrooms.

During their investigations in Tanzania, Tilya and Voogt (2002) conducted workshops and evaluated them. The intention was to evaluate not only the workshops but also the prototypes of student and teacher support materials used in the workshops to provide information about their effectiveness, practicality, validity and reliability. The results of these evaluations were then used to improve the quality of the materials for subsequent trials. As expected in developmental research, the evaluations were meant to determine the quality of the materials at specific levels in order to improve wherever necessary. The evaluations were also designed to check on the extent to which teachers accepted the materials, and the utility or appeal of the materials to teachers. It appears, developmental research was found most appropriate in this context due to the rapidly shifting state of affairs, a situation similar to what we are currently experiencing in Zimbabwe.

## 2.11 FURTHER THOUGHTS ON THE INSTRUCTIONAL DESIGN MODEL (Perspectives from new insights)



The following questions were of interest under this section in view of new ideas and renewed perspectives from literature:

- In view of the so many new perspectives encountered from the broad spectrum of the literature consulted here, should the instructional design model developed in Chapter 1 remain as it is?
- If it is to remain as it is, would it have the capacity to contain the demands and rigours of this study, given the challenges at hand?
- If it is to change, what new ideas should be accommodated?

Still in an effort to put this study into the appropriate conceptual/theoretical framework, investigations from literature yielded new insights, and a lot of improvements were made on the instructional design model, originally adopted and presented in Figure 1.1 of Chapter 1. This resulted in a revised version of the model as elaborated in figures 2.2 and 2.3. Therefore, in order to proceed with this study in a productive manner, there was need for one to visualize and see how this model could be accommodated within the context of the three secondary research questions generated for the purpose of this study as outlined in Chapter 1.

### *2.11.1 **Another look at the principles of instructional design** (A view from another angle)*

Since this study was concerned with the design, development, implementation and evaluation of instructional materials, the importance of the theory of 'educational goals,' as already indicated under Section 2.6, could not be over-emphasized. The conceptual and/or theoretical framework underpinning this study would not have been complete without a look at Bloom's Taxonomy as presented in sub-sections 2.9.1 and 2.9.2. It was on this theory that the resource materials developed for this study were anchored. The scheme developed by Bloom in 1956 involves the classification of educational/learning objectives, thereby relating them to specific classroom procedures (Good & Brophy, 1977). The advantage of this scheme is that it compels teachers to specify their goals and the means of getting there by fitting procedures and materials to instructional strategies (Sprinthall & Sprinthall, 1981).



From Sub-section 2.9.2, Bloom's system of taxonomy specifies a sequence of six stages or levels of objectives that are matched to a sequence of assessment strategies (Sprinthall & Sprinthall, 1981). The six levels include; basic knowledge, comprehension, application, analysis, objective synthesis and objective evaluation. Several authorities have developed a variety of instructional models based on Bloom's system of instructional strategies, many of which are described in Gustafson (1981) and Knirk and Gustafson (1986). Even those developed by Romiszowski (1984), Dick and Carey (1996) and Ally (1997) as already described in Chapter 1, could also be traced back to Bloom's instructional strategies. However, there have been cases where scholars have expressed considerable doubts on whether Bloom's taxonomy could qualify as a system of instructional strategies. Investigations based on the literature search conducted in this study confirm this. For example, Romiszowski (1984) asserts that, by virtue of being a taxonomy amounting to a form of model, it actually counts as a system of instructional strategies. Of late, the taxonomy has also been developed into a model comprising specific instructional strategies in the preparation of tests for subject-based curricula, particularly in training contexts (Romiszowski, 1984).

According to Gagne, Briggs and Wager (1992), society in general, the world over has determined that our school systems are not meeting our current needs and we are in a movement towards restructuring. More importantly however, in these efforts, it appears instructional practitioners are being challenged to do something about meeting some of these needs. One could for example suggest that they are expected to set new directions in these efforts by promoting a systems view for the problems facing education in general and teacher education in particular. In this direction, there has also been an increasing move to apply cognitive psychology to instructional systems, where emphasis has been placed on learner analysis, cognitive strategies, motivational strategies and information presentation strategies (Gagne, Briggs & Wager, 1992). To strengthen their argument on instructional design principles, Gagne, Briggs and Wager (1992) cite Keller's (1987) model of motivational design and stress the need to look not only at what we teach, but how we teach it, so as to make learning more meaningful. According to Keller's (1987) model of motivational design, methods of instructional design are expected to go as far as possible in defining the learning purpose of each design step in a model or instructional system. Perhaps in addition to this, we could also relate issues of 'observation' and 'measurement', where instructional systems enable one to measure the effects of phenomena that can be observed in order to determine the impact of instruction in a particular context. This is where one could argue that 'instruction' comprises a set or sets of intentional and planned events designed to facilitate the process of teaching and learning. It is on the basis of this assertion that the model in Figure 1.1 was found wanting, making it necessary to seriously consult literature, leading to the revised version in Figure 2.2 of Sub-section 2.11.2.

### *2.11.2 Revised version of the instructional design model underpinning this study* (*A new view of the whole system*)

Although there was a broad agreement with Ally's (1997) instructional design model regarding the general description of the various stages, it was discovered that the process itself could not fulfil the intended purpose in this study. Given the pattern of the arrows in Figure 1.1, progressing from one stage to another downwards in a 'non-return/one-way' fashion, the model did not portray the required constructivistic and developmental outlook. Justifiably, one might wonder how this discovery could have surfaced at this point, before conducting the study. This was one of the many preliminary findings based on the literature search. Despite being a good starting point, the original impression in the model was not in line with the thinking behind this study, given the task at hand. It was therefore necessary to modify the process by adding the stippled lines and arrows in order to represent the feedback procedures at various levels/stages of course development (see Figure 2.2). Feedback was anticipated, especially during the various stages of formative evaluation, expected to yield improvements on the instructional materials through suggestions and recommendations by teachers. Such contributions were mainly expected on areas like 'course content' and related activities for assessment.

The instructional design model in Figure 2.2 served two main purposes: to give direction to the whole of this study according to the three secondary research questions outlined in Chapter 1, and to guide the design and development of the course materials at the heart of this study. In fact, the model underpinned the whole study, especially on matters of methodology, going by the focus of the various stages in view of specific activities. For example, while the first two research questions required answers on issues relating to 'learner analysis', leading to 'content identification', the third (last) question required answers on issues to do with 'implementation and summative evaluation'. Effectively, the three secondary research questions were focused on stages 1, 2 and 7 of the instructional design models while the rest of the stages in the model were mainly used to explain methodology at various levels as explained in Chapter 3, starting from Figure 3.1.

However, all the seven stages in the model were applicable in the design, development, production, implementation and evaluation of the instructional materials.

Since the model in Figure 2.2 became the foundation of the instructional package used in this study, it was important for one to have a clear idea of what each of the seven stages entailed. There was therefore a need to make a full interpretation of the whole model, from the first to the last stage, in the following manner:

**1. Learner analysis** - *Identify learners' characteristics, preferences, motivation, level (e.g. qualifications), and present level of expertise*. According to Ally (1997), before learning materials are developed, learners' characteristics should be analyzed in order to identify their present knowledge or expertise, learning styles, and motivation (also implying needs of the learners). Such knowledge from the literature review was very important and instrumental in informing the whole study from a methodological point of view, particularly regarding decision making on sample size and participant selection. Serving technical subject teachers, specializing in Woodwork (Wood Technology and Design) and Metalwork (Metal Technology and Design) were involved. It was assumed that, understanding their characteristics as learners would help to determine the level at which the learning materials were to be developed, the format and/or structure the materials would take, and the instructional and learning strategies to be used. From their background and present status, one could determine the preferences, motivation, and present level of expertise of the teachers. In turn, this helped to determine their needs in terms of professional development. According to the constructivist view of learning, information about learners' knowledge and understanding is crucial in designing learning activities meeting the learners' needs and the challenges relating to differences between learners' prior understanding and new insights to be learnt (Bruner, 1986; Confrey, 1990; Lewis, 1993; Lewis, 1994). Details of lessons from here are presented in Chapter 3 as part of methodology under Section 3.3.



**2. Content identification** - *Specify the goal, learning outcomes and learning objectives for instruction*. Ally (1997) defines a 'goal' as a general statement that specifies what the learner will be able to achieve upon completion of a course of studies. Ideas from here were helpful in the choice of elements to include in the Material Science (MS) course. ‘Content identification’ became relatively easy after ‘learner analysis’. The intention was to accommodate the learners’ needs regarding professional growth, with specific reference to the teaching and learning of D&T. Content had to be relevant and appropriate to the given learners, confronted with a curriculum, demanding new knowledge and understanding.

According to Gagne, Briggs and Wager (1992), ‘learning outcomes’ specify results of the course and are usually skills oriented. They actually help to identify what the learner must be able to do on completion of the course. These observations seem to suggest the learning outcome being a statement containing an action verb and object. Such skills might involve the application of theoretical knowledge and consequently presuppose deep and functional understanding of theoretical concepts (Gagne, Briggs & Wager, 1992). This was the case in this study where the new curriculum required teachers to apply D&T to instruct pupils and/or students both in scientific topics and in the use of scientific concepts, principles and ideas. More specific learning objectives for teachers in D&T might, for example, be the ability to evaluate and determine the use of different materials (e.g., metals and plastics) when designing artefacts by applying scientific knowledge relating to corrosion, effects of heat and other factors. Proceedings here have shown that while learning outcomes are general, learning objectives are specific steps enabling learners to achieve the outcomes.



**3. Delivery technology selection** - *Identify the most appropriate delivery technology for instruction*. The instructional materials became part of the technology in this case. Essentially, competencies in all forms of skills, for example, cognitive and motor skills, are accommodated under this stage, usually following the statement of learning objectives (Romiszowski, 1999). Final choice of the specific technology and content delivery method depends on the nature of objectives at stake. Ally (1997:21) maintains that, “--- learning objectives are used to select the most appropriate delivery method for the instruction”. He lists the following among many: computer-managed learning, videotapes, audiotapes, CD-ROM, audio-graphics, video-conferencing, computer conferencing and the internet. Criteria for selecting instructional delivery methods usually rest upon the following factors: types of learning outcomes, nature of technology available, technical expertise of the instructor, affordability, reading level and motivation level of the learners. In some cases, learning matrices are also designed in order to have all the learning objectives levelled against their respective delivery methods (Ally, 1997).

**4. Specification of instructional and learning strategies** - *Identify the most appropriate strategies for the given learners.* Ally (1997) recommends that the process of developing learning materials should be guided by the following general principles based on specific constructivistic views of learning:

- The present level of learners should be determined so that they are taught from that level. This is how this study benefited from what happened under the first stage of the model in Figure 2.2. What happened in the first stage appears to have paved way for all the subsequent stages. One stage leading to the other, all the seven stages in Figure 2.2 are closely inter-related.
- Pre-instructional activities should be provided, in order for learners to build a framework for the new learning, expected to occur.
- The instructional process should ensure that learning is active, rather than passive.
- Learning activities that motivate learners should be included in lessons or modules.
- Meaningful learning rather than rote learning should be encouraged for better results.
- Learners should be given the opportunity to practice new skills so as to apply them in new situations.
- Corrective feedback should be provided so that learners do not repeat mistakes.

**5. Development of evaluation instrument(s)** - *Determine the most appropriate method(s) for evaluating the instruction for both, formative and summative purposes.* After learning activities in a particular unit/lesson, learners need to be evaluated to determine whether they have successfully achieved the set objectives (Ally, 1997). In the case of this study, learners had to be evaluated upon completion of every module unit. Learners' achievement levels are usually evaluated by using various types of questions, among which Popham (1990) identifies the following categories: selected-response questions; constructed-response questions; practical (laboratory) questions, and oral questions. These categories influenced the design of the evaluation instruments in this study.

Different instruments are used to test different learning outcomes (Gustafson, 1981; Gronlund, 1988). In this study 'cognitive skills' required paper and pencil tests, oral presentations, case studies, short essays and interviews. Psychomotor skills' required performance tests, on-the-job observations, and product reviews. Lastly, affective skills demanded role-playing, paper/pencil tests, and team exercises or group activities.

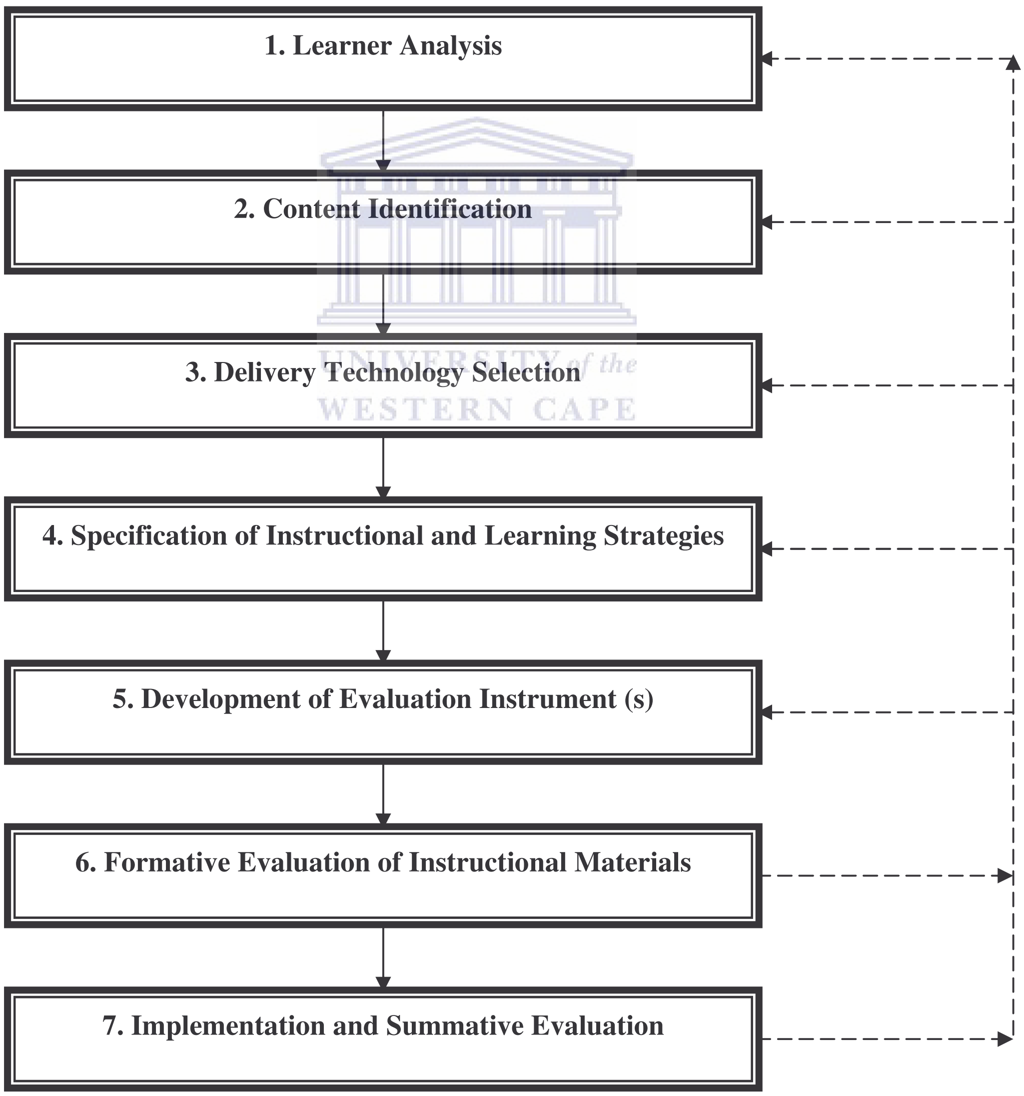


**Figure 2.2** A revised version of Ally's (1997) instructional design model used in the development of the course at the core of this study. (The added stippled lines illustrate feedback to the various stages of the course design provided by the formative and summative evaluations of the course at various levels).

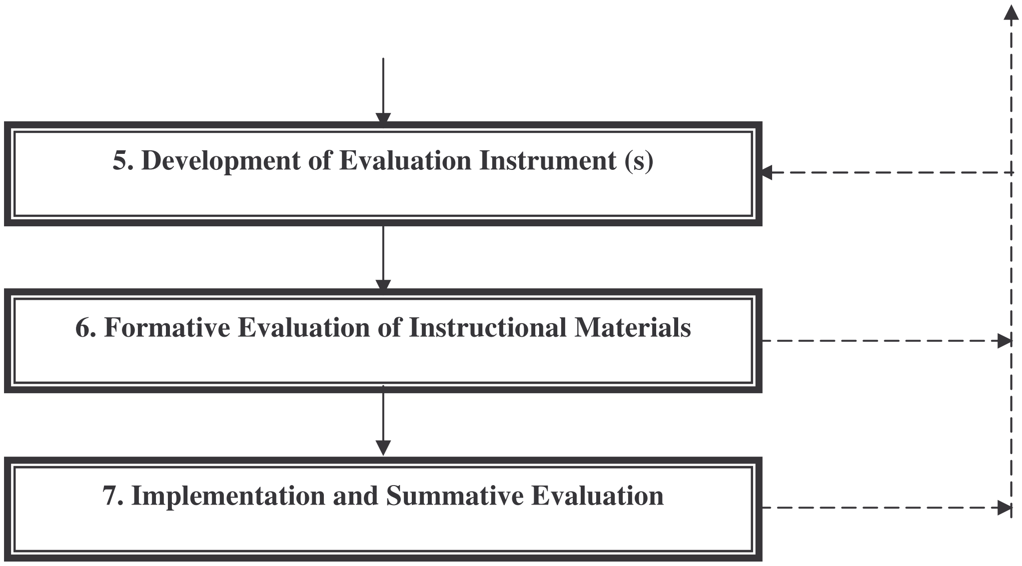
**6. Formative evaluation of the instructional materials –** *Plan this evaluation and pilot-test the learning materials in order to revise and improve them as might be necessary.* Ally (1985) recommends that after learning materials have been developed, they should be reviewed by experts before implementation. This is very important if the learning involves complex, expensive, or dangerous equipment (Ally, 1997). In this study it was not so much of any form of danger, but the expenses involved in running the course, at a time that Zimbabwe is experiencing critical economic hardships and challenges.

Experience from literature showed that sometimes it is necessary to repeat activities at various stages in most instructional design models so as to effect specific improvements at particular levels. From a D&T perspective and given the tendency in developmental research (DR), this would be normal practice. This justified the addition of the stippled lines in Figure 2.2, in order to illustrate the cyclic nature of the developmental process at various stages. In fact, this is where the principles of D&T could be said to be very much in agreement with those of 'developmental research' (DR) as applied in this study. The whole process of the D&T approach is cyclic in nature, especially when one considers the way practical problems are addressed through rigorous experimentation requiring one to generate several possible solutions before settling for a final solution (Lewis, 1995; Habermas, 1971; Salinger, 1994; Savage & Sterry, 1990a, 1990b; Buchanan, 1995; Zoller, Donn, Wild & Beckett, 1991). In view of this observation, one can argue that both D&T and DR are fundamentally based on the philosophy of constructivism as described by Baird and White (1984); Brown and Walter (1983); Bruner (1986), and Cobb (1981).

**7. Implementation and summative evaluation** - *Set up the learning environment, deliver the instruction and determine its effect on learners.* According to Gronlund and Linn (1990), the 'implementation' phase of instruction includes the preparation of all resources for the learning process. To do this holistically, the learning environment should be organized appropriately to include all the necessary and relevant equipment. In addition, the relevant human resources should also be in place, equipped with the necessary qualifications (Ally, 1997). Where members of staff need training, this should be done in advance and the effects of the training would then be evaluated by observation during implementation of instruction in a real training environment. It is important to note that this also implies the outcome of the summative evaluation being a consequence of all factors included. It might therefore be difficult to sort out whether a sub-optimal outcome was due, for example, to poor materials, poor teaching or poor training of teachers. Therefore, when designing evaluation instruments, special care has to be taken if one intends to gain deeper insights into the influence of the different aspects of an instructional package. Summative evaluation comes immediately after implementation and helps to determine whether or not the instructional materials have been effective, in terms of improving the learner's performance (Ally, 1985). While 'formative evaluation' is conducted to improve the learning materials before implementation, 'summative evaluation' is conducted to enable an organization to decide on whether to continue using a given package of instructional/learning materials or not (Ally, (1997). In most cases, summative evaluation also indicates the amount that was learned and the time required to achieve the learning objectives.



Having explained all the steps in Figure 2.2, it is now necessary to explain the sense behind the pattern of the arrows in order to be clear about their meaning and significance within the whole model. Figure 2.3 helps to elaborate on this. The arrows going downwards illustrate the sense of development from stage to stage. According to the pattern, the seventh step does not mean the end of the developmental process. From a D&T orientation, this stage means a new beginning. At this point and after a reflective evaluation, the whole process resumes backwards, or rather upwards, step by step either improving or consolidating the process. This is where the cyclic aspect of the model in Figure 2.2 comes in as the root of the 'developmental research approach' (DRA) adopted for the purpose of this study. A full description this approach is presented in Chapter 3.




NOTE**:** The 'CYCLIC' process occurs between the last two stages (6 & 7) and the rest upwards (stages 5 to 1) as indicated by the sense of all the arrows

**Figure 2.3** Explanation of the cyclic process in the instructional design model in Figure 2.2

The 'cyclic process' (CP) in this case occurs between the last two stages (6 and 7) and all the other five stages (5 to 1) upwards. Figure 2.3 clearly illustrates this action. Where evaluation shows room for improvement somewhere, the idea would be to go back step-by-step, checking to see where exactly things could have gone wrong. Conversely, where things could have gone well, the idea would then be to go back reinforcing or consolidating the process, thereby making the whole process developmental and constructivistic in nature.

In this study, the cyclic process was meant to refine the thinking process behind the design and development of the instructional materials where the pattern described by the arrows in Figure 2.2 illustrates the cycles within the respective processes. In addition, Figure 2.3 helps to clarify and elaborate on the nature of activities in Figure 2.2 by focusing on the sense and concentration of the whole cyclic process within the model. This is another way of showing how Ally's (1997) instructional design model was modified to become more or less a kind of control centre for all the events in this study.

In view of the topics covered in this chapter, several lessons were drawn from literature and this helped to clarify many pertinent issues in this study. The model elucidated in figures 2.2 and 2.3 illustrates the philosophy that guided the whole of this study according to the three secondary research question outlined in Chapter 1. As already noted, all methodological issues were clarified and straightened through lessons drawn from various aspects of the literature. The next chapter (Chapter 3) shows how the model in Figure 2.2 was used to effectively to guide operations, events and activities in this study.

# Chapter 3

# METHODOLOGY

The purpose of this chapter is to describe, explain and give an overview of the following broad methodological aspects in line with the conceptual/theoretical framework underpinning this study and the instructional design model in Figure 2.2: Methodological framework; General approach/research design; General procedures/preparations; Data collection procedures and Data analysis/statistical procedures. These aspects are featuring as sections, where specific pertinent issues are further raised and deliberated upon.

## 3.1 THE METHODOLOGICAL FRAMEWORK

Considering the nature of the issues that were to be addressed from a methodological stand point, it was necessary to establish and follow a road-map of events, from the first to the last chapter in a kind of logical framework. This is where the model in Figure 3.1 came in as a framework guiding the study from a procedural perspective. It is a flow chart showing how this chapter linked activities in the first two chapters (1 & 2) to those in the last two (4 & 5).

While there could be several explanations to Figure 3.1, depending on one's orientation, according to the philosophy motivating the path followed in this study, the primary research question was the point of departure, leading to the secondary research questions and the instructional design model. All these were issues originating from Chapter 1 before being revisited and clarified in Chapter 2. After the general preparations, data collection and analysis in this chapter; the path continues into chapters 4 and 5 where results, findings, conclusions and recommendations are presented.

Apart from being the path followed in this study, the pattern of events in Figure 3.1 also shows how the stages in Ally's (1997) instructional design model guided the various preparatory and main activities, accordingly described under the respective sections in this chapter. These activities are clearly contextualized in the framework, showing which stages were applicable at specific points.

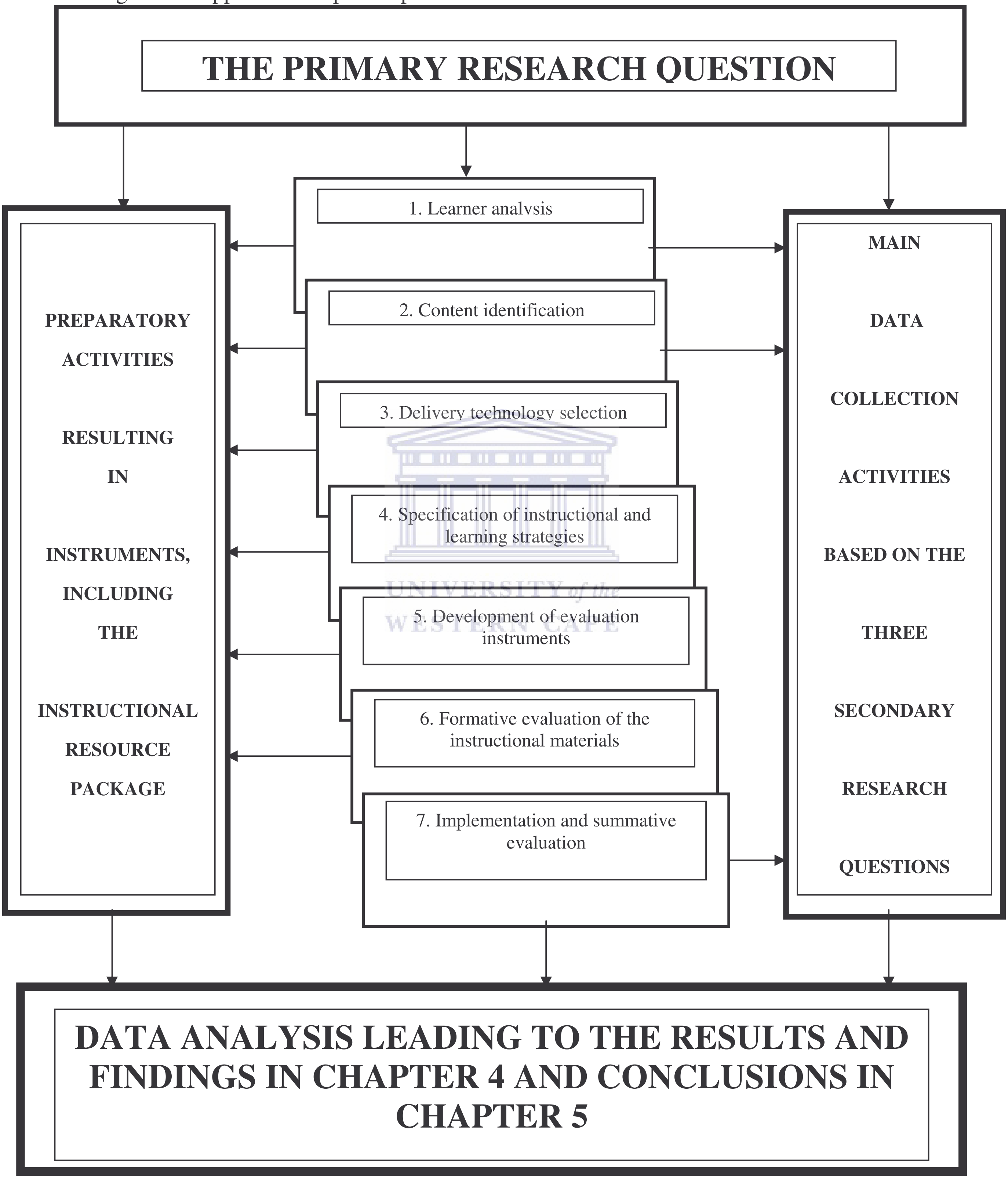


**Figure 3.1** The methodological framework, being the map followed in this study going by the stages in the instructional design model leading to the preparatory investigations, data collection, data analysis, results, findings and conclusions, from Chapter 3 up to chapters 4 and 5

## 3.2 GENERAL APPROACH AND RESEARCH DESIGN

Since this study was meant to culminate in the design, development, implementation and evaluation of a prototype programme of instructional materials, it was approached mainly through 'developmental research' (DR), located in both the quantitative and qualitative paradigms. The study was also anchored within the model originally presented in Chapter 1 as Figure 1.1, borrowed from Ally's (1997) instructional design model, adapted and modified to result in Figures 2.2. Being developmental and progressive in nature, Ally's instructional design model influenced this study in two respects as illustrated in Figure 3.1; during the preparatory investigations and in addressing the three secondary research questions. From the scope of this study, the idea was not to cover all the subject areas in the Department of Technical Education at the University of Zimbabwe, but to focus on Materials Science (MS), culminating in an exemplary course.



Following the primary research question in Figure 3.1, the three secondary research questions helped to contextualize the seven stages in Ally's instructional design model within this study. Since the purpose was to determine the effect of a specific MS course on the perceptions, understanding and knowledge of teachers regarding content in MS and instructional practice in D&T, there was need to design a special evaluation through a kind of pre- and post-test mechanism where 'learner analysis' was isolated for the pre-test while 'summative evaluation' went with the latter.

Involving both quantitative and qualitative approaches to the handling and treatment of data during collection and analysis, the study also encompassed principles drawn from case and evaluation studies. Because of the differences in their strengths and weaknesses, as noted by Patton (1990:14), quantitative and qualitative methods constituted alternative, rather than mutually exclusive strategies for research. Both quantitative and qualitative data were collected, and it was not a choice of one to the total exclusion of the other. However, given so many interviews, observations, and document analyses, the latter paradigm appeared more dominant than the former, particularly during the last phases of the study.

As already pointed out in Chapter 2 during the interpretation of Ally's (1997) instructional design model, among the several areas influenced by this model during the literature search was that of 'Methodology'. Nearly all decisions made on this aspect were inspired by the philosophy behind this model, particularly the foundation of the whole research design as shown in Figure 3.1. This is how the 7 stages from the model translated into the following phases, thereby directing the whole study as respectively explained under each phase, within the pre- and post-test parameters:

**(i)** *Learner analysis to identify appropriate content and related factors in order to inform the design and development of the instructional materials for the course*. Investigations at this level had implications on the following stages of the model, thereby impacting upon them in one way or another: Learner analysis, Content identification, Delivery technology selection, and Specification of instructional and learning strategies. These stages happen to be the first four in Figure 2.2, later contextualized as illustrated in Figure 3.1. Given the range of the activities in these stages, this is where the decision to gather information through the checklist (in Figure 3.4 and Appendix 1) and Questionnaire 'A' (in Figure 3.2 and Appendix 2) was arrived at. Another decision also made here was the use of observations during learner analysis. 'Learner analysis' was the central issue, with the rest of the stages only coming in by association. According to Gregorc (1982), Keller (1983), Kolb (1983), and McCarthy (1987), understanding the learners' background in terms of previous learning experience, motivation or interests, and learning styles, is key to the design and development of instructional materials in particular contexts. In this study, this was the stage at which the instructional materials were developed.

**(ii)** *Another round of learner analysis serving as part of the pre-test; this time to determine the prior perceptions, understandings and knowledge of teachers on the teaching and learning of specific concepts in MS within the context of D&T*. This phase was meant to consolidate the issue of 'Learner analysis' started in Phase 1. However, this time investigations were confined to Questionnaire 'A2' (see Figure 3.3 and Appendix 3). Although the main focus of investigations at this level was on Learner analysis like during Phase (i), there were also important indications towards; Content identification, Delivery technology selection, and Specification of instructional & learning strategies.

**(iii)** *Implementation of the instructional materials*. The earliest activities here were centred on the 5th stage of the model in Figure 2.2; 'Development of evaluation instruments'. Questionnaires 'A2', 'C' and 'D' were used to facilitate the 'Implementation', 'Formative evaluation' and 'Summative evaluation' of the materials. Besides the 5th stage, this phase was also founded upon the 6th and 7th, thereby marking the beginning of the post-testing activities characterizing this study.

**(iv)** *Continuation of study under the Machine Shop Practice (MSP) course in order to check on the effect of the MS course, in terms of application of theoretical knowledge in related practical activities*. Naturally, this phase was mainly based on the last or 7th stage of the model in Figure 2.2, being a continuation of events relating to post-testing activities. Although implementation of the instructional package had already commenced in the previous phase, the 'Summative evaluation' continued into the MSP course where teachers were expected to put their theoretical knowledge of MS into practical application.

**(v)** *The last round of events involving post-testing activities designed to determine the impact/effect of the treatment (implementation of the MS course) in terms of the perceptions, understanding and knowledge of teachers relating to the teaching and learning of those concepts in MS coined within Questionnaire 'A2'*. On the whole, this was a continuation of the 'Summative evaluation' started in Phase (iv). Here, attention was focused on the $7^{th}$ stage of the model in Figure 2.2.

Since Development/Developmental Research (DR) is an emergent phenomenon still unfamiliar to most people, including researchers, (as observed by Van den Akker, 1999), there appears to be a need to look more closely at what it is all about and what it really involves. This is important in order for one to see how this way of research was found suitable and appropriate in this study.

Gravemeijer (1999), Lijinse (2000) and Van den Akker (1999) are among many who have offered a working definition of DR despite a slight difference in terms of terminology where the first two refer to 'developmental research' and the last, 'development research'. However, Gravemeijer (1994) adds another dimension of terminological flavour when he uses 'developmental research' and 'design research' interchangeably in his theory of 'realistic mathematics education'. In essence, these authorities are all referring to the same thing and for the purpose of this study these terms were used interchangeably. According to Van den Akker (1999), DR is often initiated for complex, innovative tasks where very few validated principles are available to structure and support design and development activities. Such was the case in this study where DR was not viewed as a particular method, but as a label referring to various approaches to research:

> ---the label of development research may be used to refer to various kinds of research approaches that are related to design and development work (Van den Akker, 2002:52).

Involving both quantitative and qualitative methods of data collection, typical activities in DR include: literature review; participatory research; formative research, experiments, evaluations and case studies of current practices to specify and better understand needs and problems in intended user contexts (Van den Akker, 1999). Case studies of product and human resource development, as what occurred in this study, go in several cycles where one tests, adjusts and redesigns, again and again, in search of the ideal at a particular point in time. In this study such cycles were experienced at various stages and levels with typical examples including:

designing the instructional materials, trying them with one group of teachers (Intake 1) and formatively evaluating the materials unit by unit before final implementation with Intake 2, just to mention a few of the cycles illustrated in figures 2.2, 2.3, 5.1 and 5.2 for more details). This confirms Becher (1990), Chisholm (1990) and Yin's (1989) reference to case studies, describing them as being 'rigorous' and 'demanding' when appropriately and properly conducted. In many ways, this appears to be calling for serious attention to matters of design, data collection, analysis, interpretation and reporting of results and findings; thereby reinforcing Robson's (1993:5) definition of a 'case study':

> 'Case study' is a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence.



Methods of DR are not necessarily different from those in other approaches. However, more than most other approaches, DR aims at making practical and scientific contributions, involving empirical testing of prototypes (Van den Akker, 1999). Given the multiplicity of all the methods involved, one could safely argue that it is the way they are put together in a particular investigation or study that culminates in DR, making it more of a 'process' rather than a piece-meal event or a single act activity.

Van den Akker (1999:3-5) warns of the danger of confusion, in view of so many terms associated with DR and submits that, we are dealing with an emerging trend, characterized by a proliferation of terminologies and a lack of consensus on definitions. He then resolves to establish a basic structure involving the following sub-domains of education; 'curriculum', 'media and technology', 'learning and instruction' and 'teacher education and didactics'.

According to Lijnse (2000:308-326), given the shortage of pedagogical knowledge in science education, progress in the didactics of science and related areas is possible provided we intensify our search for it through developmental research comprising 'design experiments' and/or 'teaching experiments'. In this study, apart from associating developmental research with the design and development of instructional materials, the materials were expected to have a positive impact or effect, on the users (in this case teachers), thereby resulting in their professional growth and development.

## 3.3 GENERAL PROCEDURES AND PREPARATIONS

Under this section, the following aspects were of particular interest: The Population; Sample size/selection of participants and Instrumentation.

### *3.3.1 The population*

The population in this study comprised of secondary school teachers of Woodwork and Metalwork, currently qualified to teach up to 'O' Level (forms 1 to 4 or Ordinary Level). These teachers were however believed to have the potential and capacity to be staff-developed for teaching aspects of D&T at 'A' Level (forms 5 to 6 or Advanced Level) where among many, Material Science (MS) was the main focus.



### *3.3.2 Sample size and selection of participants*

Participants in this study came in two groups of serving teachers in the Bachelor of Education (B.Ed.) degree program from the Department of Technical Education at the University of Zimbabwe. The sample specifically comprised of forty-five (45) teachers drawn from the 2002-2003 Intake (Intake 1) and another 40 from the 2003-2004 Intake (Intake 2). Enrolled in two programs, the former group had 23 candidates under Wood Technology and Design and 22 under Metal Technology and Design, while the latter had 21 doing Wood Technology and Design and 19 under Metal Technology and Design. Unfortunately during the final year, Intake 2 lost one member who passed away before completion of the program. Although these two groups belonged to different intakes, they had the same background in terms of experience and previous training. All these teachers had undergone initial teacher education/training in teachers' colleges affiliated to the University of Zimbabwe where they were hosted in the Department of Teacher Education. They had either diplomas or certificates qualifying them to teach at 'O' Level.

Considering the way participants came into this study, the whole process could safely be referred to as 'Purposive Sampling'. They were studying relevant subjects and on invitation, they volunteered in. This proved very important during the course of the study, where teachers became more and more active as participants at various levels. From a total of six technical subjects, only two were of particular interest and were therefore purposefully and/or purposely selected. In this case, as already implied above, I deliberately selected two specific groups of serving teachers studying Wood Technology and Design (WT&D) and Metal Technology and Design (MT&D) within two intakes/enrolments. Being non-probability in nature purposive sampling was necessary and justified, given the purpose in this study where interest was focused upon two groups of teachers studying D&T related subject areas. These two were the only such groups at the time of study. In contrast to 'Probabilistic Sampling', the idea was to concentrate on what could technically be referred to as 'information rich cases'. The teachers who participated in this study were considered to be such cases, since they were engaged in activities related to D&T. In this study, where the problem and research questions were centred on issues relating to D&T, the teachers were expected to provide insights and answers to most of the pertinent issues at hand, thereby qualifying as 'information rich case'. I wanted to study specific cases in depth, given the need to, 'determine the impact/effect of a Material Science (MS) course on serving teachers in terms of their perceptions and knowledge/understanding regarding content in MS and instructional practice in D&T?' There was no intention or desire to generalize findings to all such cases. The idea was to study the selected groups of teachers under WT&D and MT&D without necessarily generalizing about the rest of the subjects or groups in the department. However this did not stop me from drawing specific lessons from relevant experiences wherever possible. In doing this, I was aware of Patton's (2002) assertion that purposive sampling is conducted to increase the utility of information obtained from small samples. In this regard, such sampling requires that information be obtained about variations among the sub-units before the sample is chosen (Miles & Huberman, 1988; Miles & Huberman, 1994; Miller & Benjamin, 2000). In this study, it is information about such variations among sub-groups that resulted in the selection of WT&D and MT&D teachers to the exclusion of the rest of the teachers in other technical subjects. It was after this that I searched for 'information-rich' key informants, groups, cases and events, relevant to the study. In other words, the participants and cases were chosen because they were assumed to be knowledgeable and informative about the issues that were to be investigated and studied.

Choices and decisions (e.g. choice of specific groups of participants into the study) were strengthened by the firm knowledge of Bogdan and Biklen's (1992) belief that the power or logic of purposive sampling is based on the fact that a few cases studied in depth and detail yield many insights about the topic, whereas the logic of probability sampling depends on selecting a random or statistically representative sample for generalization to a larger population. I was also aware that, probability sampling was not going to be applicable in this study since procedures such as simple random or stratified sampling would not be appropriate where: (1) generalizability of the findings is not the purpose; (2) only one or two sub-units of a population are relevant to the research problem (as was the case in this study); (3) the researcher has no access to the whole group from which s/he wishes to sample; or (4) statistical sampling is precluded because of logistical and ethical reasons (McMillan & Schumacher, 1993). Decisions on sampling mechanisms were also directed and guided by a full awareness of the following types of purposive sampling; site selection, comprehensive sampling, maximum variation sampling, network sampling, and sampling by case type as outlined and described by Cohen, Manion and Morrison (2003) and McMillan and Schumacher, (1993). Hence in this study, it was more or less a case of hand picking all the cases that were to be studied, while at the same time allowing for an element of voluntary participation at various levels. This is exactly how the serving teachers identified above, came to participate in this study.

Given this background, the inclusion of participants was on the basis of judgment, regarding their typicality. This was a sample assumed and believed to be satisfactory to the needs of this study, in terms of information.

### *3.3.3 Instrumentation*

**The instructional design model as a foundation for instrumentation and approach**

To address the research questions (primary and secondary) raised in this study, several instruments and approaches were designed, tried/tested and implemented within the confines of the instructional design model in Figures 2.2, as elaborated by the methodological framework in Figures 3.1. The main instruments included; the syllabus check-list, questionnaires, interview guides and the instructional resource package itself. In each case, the intention was to cover particular stages in the developmental research process by means of specific instruments in conjunction with their associated mechanisms and approaches. The design and application of the various instruments, mechanisms and approaches went according to specific stages and phases as explained under Section 3.2. Therefore, individual instruments, mechanisms and approaches are hereby described within the context of the appropriate individual stages and phases of the study (figures 2.2 and 3.1).



Although the seven stages in Ally's (1997) instructional design model did not impact upon the three secondary research questions to the same extent, they were all essentially, connected to the primary research question. As to how the various instruments, mechanisms and approaches related to individual stages within the model, further explanations have been made at the same time with their descriptions at appropriate levels in this chapter and elsewhere (also see the methodological framework in Figure 3.1.

Closely following one of Patton's (1990) recommendations regarding qualitative research (which happened to be a major paradigm in this study), there were moments when I, as researcher, really felt being part of the instrumentation. According to Patton (1990:14):

> While in quantitative research, the focus is on the measuring instrument, in qualitative inquiry the researcher is the instrument. Validity in qualitative methods, therefore, hinges to a great extent on the skills, competence, and rigor of the one doing the fieldwork.

For the sake of space, all figures illustrating instruments from 3.2 to 3.10 have been summarized and only the main features are shown in each case. More details for figures 3.2 to 3.7 are respectively shown in appendices 1 to 6. The observation schedules in figures 3.8 and 3.9 are also summarized for the same reason; space.

**Learner analysis**

Being the first stage in Ally's (1997) instructional design model, activities under this stage were specifically meant to provide answers to the first and second secondary research questions outlined in Chapter 1 and going as follows:

- What perceptions of specific aspects of Design and Technology, as an approach, do teachers hold?
- What knowledge/understanding of specific concepts in Material Science do teachers hold in relation to the teaching and learning of Design and Technology?



In one way or another, the answers obtained here also helped in the identification of content for the instructional resource package at the heart of this study.

This study was about determining the effect of a package of instructional materials on a particular group of teachers through developmental research, specifically focusing on their perceptions, understandings and knowledge levels in respect of content in Material Science (MS) and instructional practice in Design and Technology (D&T). It was therefore necessary to closely analyse and understand the type, kind and nature of the teacher (learner) under study. From the general description of this stage in Chapter 2, Ally (1997) recommends one identifying learners' characteristics, qualifications, preferences, motivation, needs, present level of expertise and all the related factors, as a matter of procedure when designing instructional materials. This is exactly what happened in this study where special, relevant and appropriate instruments had to be designed in line with this task. The two main instruments used here were questionnaires

‘A’ and ‘A2’. Most of the data expected from these questionnaires were quantitative in nature, except for those drawn from sections where respondents were either required to provide demographic data or to elaborate and explain specific issues.

***Learner analysis questionnaire*** *(Questionnaire ‘A’))*

This questionnaire was used during the early part of the study to gather part of the data that were used for the preparatory/planning phase of the instructional materials. In order to come up with a suitable, relevant and appropriate package of learning materials, for a specific group of learners, such as was the one comprising the teachers in this study, it was important to understand them in various respects, hence the variety of angles implied in the various sections of the questionnaire in Figure 3.2 and Appendix 2.

While this questionnaire was mainly focused on Stage 1 of the model in Figure 2.2 (Learner Analysis), most of the data and the findings obtained had implications on issues relating to most of the other stages in the model. For example, after understanding the learner during the initial stages, one had ideas possibly helping to inform decisions on the following subsequent stages: (2) Content identification, (3) Delivery technology selection and (4) Specification of instructional and learning strategies. This clearly shows that while ‘learner analysis’ was an issue in addressing the first two secondary research questions as indicated above, it was also one of the key issues in the preparation of the instructional materials, going by the 7 stages in the instructional design model in Figure 2.2. The outline of stages from this model, implied in the data obtained from Questionnaire ‘A’ is a clear testimony of this questionnaire contributing immensely towards the preparatory phases of the study.

In terms of design and structure, this questionnaire had six parts comprising key items and asking teachers to provide information considered critically important in decision making on issues relating to the design and development of the proposed instructional materials. While Figure 3.2 shows a summarized version of the Learner Analysis Questionnaire (Questionnaire ‘A’), Appendix 2 shows the full details. Perhaps, going by the sense behind each part from (A) to (F), one could see how the data anticipated related to specific stages in the instructional design model in Figure 2.2. In this case, focusing on Learner analysis, substantial amounts of data were expected from parts (A), (B) and (E).

Starting with Part (A) of the questionnaire and focusing on 'learner analysis', one can see that the nature of demographic data requested for, from items 1 to 12, were very informative. Of particular interest were aspects like; qualifications, expertise in the subjects taught and years of experience in teaching.

Part (B) was another source of information relating to 'learner analysis'. At this stage, teachers were expected to give more details of their 'level of expertise', as taken from their previous training during initial teacher education/training. Such information was an important indication of the aspects teachers were satisfied with from their initial teacher preparation and those, they considered lacking. It was assumed this would help to reveal areas in which teachers needed help in terms of professional development, thereby implying their preferences and motivation as recommended by Ally (1997).

Still on the issue of 'learner analysis', asking teachers to indicate their willingness to act as resource persons, as was the case in Part (E) of Questionnaire 'A', was a way of checking on their confidence, in view of their current level of expertise. The anticipated data were expected to give an idea of their interests on indicated aspects.

**Learner Analysis Questionnaire** (Questionnaire 'A')

**(A) DEMOGRAPHIC DATA**
1. Age: ___ 2. Gender (M/F): ___ 3. College of initial training: __ 4. Period of training: __ 5. Qualification (s) obtained: __ 6. Main subject(s) trained for: __ 7. Subject(s) currently teaching: ___ 8. No. of years teaching: __ 9. Sch. currently teaching: _____ 10. District sch. is situated: _______ 11. Location of sch., rural or urban: ___ 12. Your subject in B.Ed program: __.

**(B) INITIAL TEACHER TRAINING:** 1. Elements **(a)** to **(g)** are from 'O' Level Wood/Metalwork syllabi. Indicate the extent to which you feel prepared to handle them when assisting pupils at 'O' Level (**1** = NOT AT ALL; **2** = NOT QUITE; **3** = UNDECIDED; **4** = WELL ENOUGH; **5** = VERY WELL).

**(C) RELATING 'O' and 'A' LEVEL SYLLABI (Regarding D&T**) 1. On **(a)** to **(g)**, indicate extent to which they could be pre-requisite to D&T at 'A' Level (**1** = NOT AT ALL; **2** = NOT QUITE; **3** = FAIRLY SO; **4** = MUCH SO; **5** = VERY MUCH).

**(D) YOUR OPINION ON ITEMS FOR THE PROPOSED IN-SERVICE PROGRAMME** 1. **(a)** to **(p)** from 'A' Level D&T syllabus. Indicate the ones you feel should be included in an in-service program in your subject area according to the following scale: **1** = NOT AT ALL IMPORTANT; **2** = NOT QUITE IMPORTANT; **3** = FAIRLY IMPORTANT; **4** = IMPORTANT; **5** = VERY IMPORTANT.

**(E) INDICATION OF WILLINGNESS TO ACT AS RESOURCE PERSON** 1. (a) **Yes** or **No**: ___.(b) If 'Yes', indicate degree of your interest on specific areas, depending on which ones you would like to be involved in, from **(a)** to **(p)**. Follow the given scale, where: **1** = NOT AT ALL INTERESTED; **2** = NOT QUITE INTERESTED; **3** = FAIRLY INTERESTED; **4** = INTERESTED; **5** = VERY INTERESTED.

**(F) ANTICIPATED LOGISTICAL AND PRACTICAL PROBLEMS** 1. Indicate the degree to which you agree or disagree with the following being anticipated problems in the teaching/learning of D&T at 'A' Level, with specific reference to your situation (where: **1** = STRONGLY DISAGREE; **2** = DISAGREE; **3** = UNDECIDED; **4** = AGREE; **5** = STRONGLY AGREE.

**Figure 3.2** A summarized version of the Learner Analysis Questionnaire (Questionnaire 'A')



After Part (A) where teachers were asked to provide demographic data, the main feature of this questionnaire was the 5-point Likert-like scale, featuring on the rest of the parts, from (B) up to (F). On all these components, Item 2 gave teachers a chance to air their views through comments of their choice. This questionnaire brought in, both quantitative and qualitative data.

***Pre & post-test questionnaire*** *(Questionnaire 'A2')*

This was another questionnaire designed to deal with the issue of 'learner analysis'. Being a pre-and-post-test instrument for the whole study, this questionnaire was directly targeted at addressing the primary research question underlying this study and broadly going as follows: 'What effect would a specially designed, developed and implemented Material Science (MS) course have on serving teachers in terms of their perceptions and knowledge/understanding regarding content in MS and instructional practice in D&T?'. Given its purpose, this questionnaire was also touching on all the three secondary research questions, where in addition to the first two already stated at the beginning of this sub-section, the third one was: ‘To what extent are teachers competent to apply the knowledge gained from the Material Science course in solving practical problems under the Machine Shop Practice course?’.

On the whole, the purpose of pre- and post-testing with this questionnaire was to establish the starting point before coming to an end result in terms of professional development where teachers were expected to start somewhere before the course and end somewhere after the course. This justified the need for ‘learner analysis’ where we needed to have an idea of the learner we started off with as compared to the one we ended up with. This was an effective mechanism to determine the impact of the MS course at the heart of this study, in view of the primary research question. Section 1.2 in Chapter 1 provides more details on the primary research question and the related secondary questions.

The extent to which this questionnaire related to the instructional model in Figure 2.2 in particular and the whole study in general, depended on the level at which it was administered. For example, at pre-test level, given the nature of investigations, the data collected were first and foremost, meant to address issues specifically relating to (1) Learner analysis, with direct implications on (2) Content identification, (3) Delivery technology selection and (4) Specification of instructional and learning strategies. As already noted under Questionnaire ‘A’, the idea behind analysing and understanding the learner was to identify relevant and appropriate content which would in turn be followed by the selection of appropriate delivery technology going together with the relevant instructional and learning strategies. And that way, ‘learner analysis’ became the key to the rest of the stages in the instructional design model. On the other hand, at post-test level, the data collected were specifically meant to determine the impact of the instructional materials on the perceptions, understanding and knowledge of teachers regarding content in MS and instructional practice in D&T; an issue at the core of this study. Logically, this followed implementation of the materials and one wanted to check on what this had done to the learners in terms of gaining new perceptions, understanding and knowledge. This was a form of summative evaluation of the instructional materials in particular and the whole project in general, thereby making the whole study evaluative in nature.

Figure 3.3 shows a summarized version of Questionnaire 'A2' while Appendix 3 shows the whole instrument. Following pre-testing where the focus was on 'learner analysis', at post-test level, the questionnaire was mainly focused on the $7^{th}$ stage of the model in Figure 2.2, involving 'Implementation and summative evaluation' of the instructional resource package. This is where this questionnaire, linked the $1^{st}$ and $7^{th}$ stages in the model. Administering it at pre-test level allowed for 'learner analysis' before the course while at post-test level meant 'learner analysis' after the course to determine the difference in perceptions, understanding and knowledge levels at both ends; entry and exit.

**Pre & Post-Test Questionnaire** (Questionnaire 'A2')

**(A) Demographic Data:** 1. Candidate Number: __ (if you wish) 2. Age: ___ 3. Gender (male/female): ___.

**(B) Perceptions on Selected Items:** Indicate --- teaching and learning of MS in D&T. Scale: **1** - STRONGLY DISAGREE; **2** – DISAGREE; **3** – UNDECIDED; **4** – AGREE; **5** – STRONGLY AGREE.

| ITEMS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. When teaching and learning MS, --- through the so-called subject integration. | | | | | |

**(C) Knowledge of Materials**: Indicate --- disagree with the following statements relating to materials. Scale: **1** - STRONGLY DISAGREE; **2** - DISAGREE; **3** - UNDECIDED; **4** - AGREE; **5** - STRONGLY AGREE

| ITEMS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Electrons differ, depending on the types of materials. | | | | | |

**(D) Level of Confidence on Selected Items:** MS is --- at 'A' Level. Use the following scale: **1**- NOT AT ALL; **2** - NOT QUITE CONFIDENT; **3** –FAIRLY CONFIDENT; **4**-CONFIDENT; **5**-VERY CONFIDENT.

| ITEMS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. ENGINEERING MATERIALS IN GENERAL | | | | | |
| 2. METALLIC STRUCTURES | | | | | |
| 3. EFFECTS OF STRESS AND TEMPERATURE ON METALS | | | | | |
| 4. ENGINEERING ALLOYS (Non-ferrous) | | | | | |
| 5. STEEL, CAST IRON, DUCTILE IRON and MALLEABLE IRON | | | | | |
| 6. COMPOSITE MATERIALS; Including Concrete and Wood | | | | | |
| 7. PLASTICS | | | | | |

**Figure 3.3** A summarized version of the Pre & Post-Test Questionnaire (Questionnaire 'A2') (for more details, also see Appendix 3)

As shown in Figure 3.3, the questionnaire had four main parts; (A), (B), (C) and (D). While part (A) asked for demographic data, the rest, from (B) to (D) were Likert-like scales asking teachers to indicate the following: Perception on selected items; Knowledge of specific concepts in MS, and Level of confidence on selected items, regarding teaching at 'A' Level.

**Content identification**

According to Ally (1997), this is the point at which one would need to specify the goal, learning outcomes and learning objectives for instruction in a given situation. This was taken seriously during the design and development of the instructional materials.

Ally (1997) defines a 'goal' as a general statement specifying what the learner would be able to achieve by the end of a course of studies. There was therefore a need in this study, for one to be sure of what exactly the learner was expected to achieve in terms of perceptions, understandings and knowledge. This was then the basis of all the ideas applied in the choice of elements to include in the MS course. In relating 'content identification' to 'learner analysis', the intention was to accommodate the learners' needs in terms of professional growth with specific reference to the teaching of MS within the context of D&T. The idea was to make the content as relevant and appropriate as possible to a particular group of learners (teachers), facing a new curriculum, demanding a lot in terms of perceptions, understanding and knowledge. Gagne, Briggs and Wager (1992) assert that, besides specifying the results of the course, 'learning outcomes' are also skills oriented. This meant accommodating specific skills in the content, in relation to the demands of the course where the application of theoretical knowledge suggested a high functional understanding of theoretical concepts. Therefore, to identify relevant/appropriate content, the Syllabus check-list and Questionnaire 'A' were used.

*Syllabi check-list*

Information obtained with this instrument (Figure 3.4 was very important in deciding what items to include in the proposed MS course. It also helped to inform the design of the instructional materials by recognizing the previous and current experiences of the concerned teachers from their background teaching Woodwork and Metalwork at 'O' Level. At this point, 'Content identification' closely related to 'Learner analysis' within the instructional design model in Figure 2.2. The three documents used in the design of this instrument included the following syllabi: 'O' Level Woodwork (Subject No. 6035), 'O' Level Metalwork (Subject No. 6045) and the 'A' Level D&T (2002 version). The intention was to determine the extent to which the first two syllabi related to the third one. It was hoped, this would help to indicate those aspects one could consider to be linking the two traditional subjects to the more progressive area of D&T. The belief was that, since teachers in this study were already qualified to teach both traditional subjects at 'O' Level, identifying such relationships would help to isolate and determine what aspects teachers were already familiar with, and which ones were new. The latter therefore required more attention in the intended instructional resource package.



| **ITEMS AND ATTRIBUTES IN 'A' LEVEL SYLLABUS** | **M/W** | | **W/W** | |
|---|---|---|---|---|
| | **Y** | **N** | **Y** | **N** |
| **A.** **AIMS**:- Students should be encouraged to; | | | | |
| - develop/sustain innovation, creativity and design & technology capability. | | | | |
| **B.** **OBJECTIVES** | | | | |
| **(a)** Knowledge and Understanding:- Students should demonstrate knowledge and understanding in relation to; | | | | |
| - materials and components for the production of artefacts; etc | | | | |
| **(b)** Design Analysis (generation of ideas and synthesis) – Students should be able to; | | | | |
| - prepare a design brief relating to a situation of need. | | | | |
| **(c)** Practical Implementation:- Students should be able to; | | | | |
| - plan and organise the procedure to implement a design proposal. | | | | |
| **C.** **CONTENT**:- Content would include the following: | | | | |
| - The theory of design and technology | | | | |

**Figure 3.4** A summarized illustration of the syllabi check-list

In terms of design, the syllabus check-list was founded upon the 2002 'A' Level D&T Syllabus, where I took advantage of the stated aims, objectives and content items. This formed the basis of the structure within which the 'O' Level Woodwork and Metalwork syllabi were compared against the 'A' Level syllabus, to determine the extent to which they could contribute towards the foundation of the course. This comparison was based on a kind of document analysis, bringing the three syllabi together as shown in Figure 3.4.

Figure 3.4 shows a summarized version of the check-list, while Appendix 1 shows all the details, including the pattern that emerged after completion, clearly showing areas of agreement and those of difference. This resulted in a pattern that helped in the identification of relevant and appropriate content for the instructional materials. For example, those aspects or subject areas that dominated the 'O' Level syllabi would either be left out completely or be included for the sake of foundation building in the in-service programme. A similar purpose could be said about questionnaires 'A' and 'A2' in figures 3.2 and 3.3 in addition to the passages below, concerning these questionnaires.



***Learner analysis questionnaire*** *(Questionnaire 'A')*

Besides 'learner analysis', this questionnaire was also designed to address the issue of 'ccontent identification' going by the instructional design model in Figure 2.2. From the six parts comprising this questionnaire as already indicated under 'learner analysis', three were of particular interest here; (B), (C) and (D). Respectively, these parts had to do with; initial teacher training, relationship between the 'O' and 'A' Level syllabi in terms of content and opinions on selected items for the proposed in-service programme.

In Part (B), teachers gave an idea of how well their initial teacher education/training had prepared them to each at 'O' level. This helped to indicate the strengths and/or weaknesses of the foundation teachers had received during their initial preparation in teachers' colleges. Such indications also helped to unearth those specific areas where teachers lacked and therefore required assistance in terms of learning and professional development.

In Part (C), asking teachers to indicate the extent to which they thought specific areas, taken from the Wood and Metalwork 'O' Level syllabi could be pre-requisite to D&T at 'A' Level was a way of engaging teachers actively in the selection/identification of content. These were likely to be the same areas they found difficult to teach at 'O' Level, thereby coinciding with those in which they felt inadequately prepared to teach at 'O' Level, as they could have indicated under Part (B). Such areas deserved special attention in the proposed instructional materials, designed to prepare them for teaching at 'A' Level.

In Part (D) of the questionnaire, teachers expressed their views and opinions on items selected for the in-service programme and by so doing, they had another chance to contribute towards the identification of content for the proposed programme. Figure 3.2 and Appendix 2 show details of Questionnaire 'A'.

Although the active participation or involvement of teachers through investigations based on questionnaire 'A' was fruitful in the identification and selection of content for the instructional materials, investigations did not end on answers provided by the teachers. There was need to seek further guidance from various authorities as indicated and reflected in the literature consulted as reported in Chapter 2.

**Delivery technology selection**

After 'learner analysis' and 'content identification', the next step was to identify the most appropriate delivery technology for the instruction. At this point, there was a sense in which the whole package of instructional materials qualified and became part of the delivery technology called for here. In essence, competencies in all forms of skills; for example cognitive and motor skills, were accommodated under this stage, following the statement of learning objectives, as recommended by Ally (1997) and supported by Romiszowski, 1999. The package, at the heart of this study was a culmination of the outcome of investigations carried out under (1) 'Learner analysis' and (2) 'Content identification'. These first two stages of the instructional design process had depended on investigations that were done through the Check-list and Questionnaire 'A'. From Questionnaire 'A', parts (A), (B), (C), (D) and (E) were collectively applicable on learner analysis and content identification. However component (F) was particularly relevant for 'delivery technology selection' and teachers were asked to share their views on a list of what were considered to be 'anticipated logistical and practical problems' (Figure 3.2 and Appendix 2).

From Ally's (1997) list of instructional technologies (comprising the following among many: computer-managed learning, videotapes, audiotapes, CD-ROM, audio-graphics, video-conferencing, computer conferencing, internet and printed materials), the last was found most appropriate in this study and involved the design and development of the relevant modular materials (Figure 3.5 and Appendix 6). In this case, I settled for the instructional package comprising modular materials after considering the general criteria proposed by Ally (1997) as being based upon the following factors; types of learning outcomes, nature of technology available, technical expertise of the instructor, affordability, reading level of learners and their level of motivation. Drafts of learning matrices were also designed to give an idea of how all the learning objectives could be levelled against their respective delivery methods and specific aspects of the chosen technology as recommended by Ally (1997).



***The instructional resource package***

This package was actually the specimen program comprising mainly the module and its various components. Apart from content, the other major components of the module included, practice/group activities, self assessment questions, reflection activities and unit/module tests. In order to develop a useful and meaningful programme, there was need to include relevant, appropriate, valid and reliable or accurate information. This information was required to cover the following topics as reflected in Figure 3.5: Engineering materials; Metallic structures; Effects of stress and temperature on metals;

Engineering alloys; Steel, cast iron, ductile iron and malleable iron; Composite materials, and Plastics. In order to secure reliable information for the relevant instructional materials, several sources were consulted under the respective unit areas, depending on focus.

*Engineering materials in general* - This unit was concerned with the atomic structure of materials, the electronic configuration of elements, three families of engineering materials and the classification of materials in the periodic table. To secure information covering these areas, the following sources were consulted: Brandt (1985); Brown, & Masters, (1982); Flinn and Trojan (1975); Flinn and Trojan (1981); John (1992) and Singh (1987).

*Metallic structures* - This unit was concerned with the atomic/electronic theory, metallic bonding, the periodic table and the effect of heat on metallic structures. The following sources were consulted: Brandt (1985), Flinn and Trojan (1981), John (1992), Gettys, Keller and Skove (1989), Olivo and Olivo (1978), Singh (1987) and Van Vlack (1982).

*Effects of stress and temperature on metals* - This unit focused upon the effect of heat, cold working and plastic strain on metallic structures. The relevant information was mainly sourced from Flinn and Trojan (1981), Olivo and Olivo (1978), and Singh (1987).

*Engineering alloys* (non-ferrous) - This unit was generally concerned with issues relating to; non-ferrous alloys, corrosion in metals, corrosion resistance of non-ferrous metals, solid solution mechanisms, and the processing/production of materials. Useful notes and lessons came from several authorities, chief among which were; Brandt (1985); Brown, & Masters, (1982); Callaghan (1982); Carbone and Corl (1982); Cook and Smith (1982); Dunbar and Showak (1982); Guttman (1982); John (1992); Johnson and Pavlik (1982); Mattsson and Holm (1982); McCaul and Goldspiel (1982); Mikhailovsky (1982); Ross and Shaw (1982); Warwick and Hampshire (1982), and Wieser (1982).

*Steel, cast iron, ductile iron and malleable iron* - This unit focused on concepts and issues relating the following phenomena; heat transfer in metals, thermal conductivity, iron–iron carbide phase diagram and the effect of carbon on the structure of iron based materials. The main sources of information included: Flinn and Trojan (1981); Gettys, Keller and Skove (1989) and Olivo and Olivo (1978).

_Composite materials_ - This unit was concerned with the physics and chemistry of materials, the behaviour of materials under different conditions, the need to strengthen materials in various applications, three distinct axes in wood, and the classification of materials. Sources of information on this area included: Flinn and Trojan, (1981); John, 1992, and Van Vlack, (1982).

_Plastics_ - This unit involved knowledge about the chemistry and physics of plastics, types of plastics, processing of plastics, and the relationship between plastics and metals regarding methods of processing. Information for this topic was obtained from Anderson, Leaver, Rawlings and Alexander (1990) and Flinn and Trojan (1981).

The principles that guided the design, development and implementation of this package were mainly anchored on the instructional design model in Figure 2.2 adapted and developed for this study as explained and described in chapters 1 and 2. Work on this package took place during the preparatory stages of this study with the help of the 45 serving teachers in Intake 1. These teachers participated and contributed to this challenge by responding to questionnaires 'A' and 'C', resulting in the development and formative evaluation of the instructional materials. Figure 3.2 and appendix 2 show details of Questionnaire 'A' while Figure 3.6 and Appendix 4 show details of Questionnaires 'C'. It is also from among the teachers in Intake 1 that the team of 13 prospective resource persons was drawn.

Two weeks before class presentations, trainee resource-persons from Intake 1 were asked to study and familiarise themselves with the materials. They divided themselves into two groups of 6 and 7 members and brain-stormed, shared ideas and aired their views on areas they thought the materials could be improved before implementation with their colleagues in Intake 2. Several of their suggestions (especially on suggested activities and unit tests) were taken on board, resulting in a lot of improvements in the materials. In some cases, issues raised were simply aspects requiring clarification here and there in specific places. It was these early investigations and activities at preparatory levels that culminated in the specimen instructional materials comprising the 60 hour MS course in Figure 3.5 and Appendix 6.

**D&T.ED. - MODULE No. DTEMOD3: MATERIAL SCIENCE** (Evolution & nature of materials, Materials & their properties, Materials processing and Materials & process selection)

**Module Time**: 60 hours
**Overall Course Aim(s)**
The main purpose of this course is to give you (prospective D&T teachers) a strong theoretical background that would enable you to teach MS at 'A' Level. Although this course is mainly theoretical, an effort will be made to engage you in simple illustrations, demonstrations and laboratory activities wherever relevant and appropriate. You will also be expected to apply what you learn in this course when you go for your MSP course.
**Overall Course Objectives**
By the end of this course, **you** should be able to do the following:
* Identify the atomic structures of various elements (materials);
* Place the various engineering materials into their respective family groups, **metallic**, **ceramic**, and the **polymeric**; * etc.

**CONTENTS**

<u>**UNIT 1**</u>: THE THREE FAMILIES OF ENGINEERING MATERIALS

| | | | |
|---|---|---|---|
| 1.0 Introduction | 1.2.1 The structure of materials | 1.4 Practice Activity or Activities | 1.7 Reflection |
| 1.1 Unit Objectives | 1.2.2 The metallic bond | 1.5 Group Activity or Activities | 1.8 Unit Test 1 |
| 1.2 Unit Content | 1.3 Unit Summary | 1.6 Self-Assessment | |

<u>**UNIT 2**</u>: METALLIC STRUCTURES (The Unit Cell)
<u>**UNIT 3**</u>: EFFECTS OF STRESS AND TEMPERATURES ON SIMPLE METAL STRUCTURES
<u>**UNIT 4**</u>: ENGINEERING ALLOYS (Non-ferrous)
<u>**UNIT 5**</u>: STEEL, CAST IRON, DUCTILE IRON and MALLEABLE IRON
<u>**UNIT 6**</u>: COMPOSITE MATERIALS, INCLUDING CONCRETE AND WOOD
<u>**UNIT 7**</u>: PLASTICS (High Polymers)

| | | | |
|---|---|---|---|
| 7.0 Introduction | 7.2.1 Polymeric structures | 7.4 Practice Activity or Activities | 7.7 Reflection |
| 7.1 Unit Objectives | 7.2.2 Polymerization types | 7.5 Group Activity or Activities | 7.8 Unit Test 7 |
| 7.2 Unit Content | 7.3 Unit Summary | 7.6 Self Assessment | |

MODULE TEST 1 (Units 1-7) and MODULE TEST 2 (Units 1-7)

**Figure 3.5** A summarized course outline of the module used in this study

The course was later implemented with teachers in Intake 2, before their course in MSP. The course outline in Figure 3.5 was specifically for MS. MSP was based on its own course outline. However, although these two outlines were not exactly the same, they were in many ways closely related and deliberately designed to reflect a lot of each other. In various places, there were statements implying demands where teachers were expected to apply their knowledge of MS in solving practical problems in MSP. This is why the process of determining the effectiveness of the MS course on the perceptions, understanding and knowledge of teachers involved these two courses. According to plan, Questionnaire 'A2' (Figure 3.3) was designed to allow for a comparison of experiences through pre- and post-testing. The latter (post-test) was divided into two (i.e. post-MS and post-MSP). This comparison served to determine the exact impact of the MS courses at the two last levels (For more details, see sections 3.4 and 3.5 in this chapter).

For the sake of space, Figure 3.5 has been summarized to show only the main features of the course outline while Appendix 6 shows the full details. Although all content items are shown for units 1 and 7, only the main unit areas are shown in the rest.

The two module tests comprised of items drawn from all the units and, being a major element of the course, these tests were actually developed and collapsed into a final examination for the purpose of final assessment (See Appendix 27). On the other hand, individual unit tests were used for coursework purposes. During the course of studies, care was taken to temporarily remove both module tests from the materials given to the teachers. They were only confronted with the materials from these tests during the final examination supervised under the general regulations of the University of Zimbabwe.

**Specification of instructional and learning strategies**



The task at this stage was to identify the most appropriate strategies that could be employed in the teaching and learning of the particular crop of learners (teachers) in this study. Coming after 'learner analysis', 'content identification' and 'delivery technology selection', this exercise was reasonably easy. In short, one needed to strategize ways of effectively applying, harnessing and taking advantage of the content at hand, given the specific objectives towards the intended outcome in teaching and learning. As recommended by Ally (1997), pre-instructional activities like group discussions and brain storming over issues relating to the instructional materials were meant to allow teachers to build a framework for the new learning that was anticipated.

Notable strategies incorporated into the structure of the instructional materials included deliberate measures to ensure that;

- learning was going to be active, rather than passive thereby promoting active learner participation.

- learning activities that were going to motivate learners were included in the lessons/modules and the whole instructional process.
- meaningful, rather than rote learning was going to be encouraged for better results.
- learners were going to be given the opportunity to practice new skills so that they could apply such skills in new situations.
- corrective feedback would be provided so that learners would not repeat mistakes.

These strategies were adapted from the ‘A’ Level D&T Syllabus (2002 version), strongly influenced by Norman, Riley, Urry and Whittaker (1990) and Garratt (1995). A close examination will show that they all had implications on issues to do with perceptions, understanding and knowledge as coined within the philosophy guiding this study and they were actually vivid in the instructional materials, as reflected in Figure 3.5 and Appendix 6. In addition, some of these strategies were fulfilled during the MSP course that subsequently followed the MS course. This was another platform where these courses shared a lot.



**Development of evaluation instruments**

This was the point at which I had to determine the most appropriate method(s) for evaluating instruction for both, formative and summative purposes. According to Ally (1997) and Romiszowski (1999), after learning activities in a particular unit or lesson, learners need to be evaluated in order to determine whether or not they have successfully achieved the set objectives.

Besides having learner achievement being evaluated by means of the unit and module tests reflected in Figure 3.5 and Appendix 6, the materials themselves also needed to be evaluated in order to determine their effectiveness and suitability in view of the learners needs. This is where questionnaires ‘C’ and ‘D’ where used (figures 3.6 & 3.7 and appendices 4 & 5). These instruments were used respectively for the formative and summative evaluation of the materials.

In addition to questionnaires ‘C’ and ‘D’, post-tests with Questionnaire ‘A2’ (post-MS and post-MSP) were part of summative evaluation. Two interview guides (for cohorts 1 and 2) and two observation schedules (for class and workshop activities) were also developed for the summative evaluation of the whole programme associated with this study.

**Formative evaluation of the instructional materials**

In the process of designing and developing the instructional materials, this exercise was conducted with the help of the 45 teachers in Intake 1. The process involved trial running the materials in order to revise them. This is where Questionnaire (C) was used.

Ally (1985) recommends that after learning materials have been developed, they should be reviewed by experts before implementation. The experts in this case were teachers belonging to the above-mentioned intake, especially those 13 who later qualified as resource persons.

***Formative evaluation questionnaire*** *(Questionnaire ‘C’)*



This questionnaire (Figure 3.6) was completed by teachers in Intake 1 to evaluate the instructional materials, unit by unit before final implementation with Intake 2, in line with the 6th stage of the model in Figure 2.2. However, findings from here had implications on the 1st, 2nd, 3rd, 4th and 5th stages of the model. For example, most of the improvements suggested had a bearing on: Learner analysis, Content identification, Delivery technology selection, Specification of instructional/learning strategies and Development of evaluation instruments.

In terms of design and structure, the questionnaire comprised of two main parts; (I) and (II), which respectively asked teachers to provide their demographic data and opinions on various aspects within the modular units.

**Formative Evaluation Questionnaire** (Questionnaire ‘C’)

**(I) DEMOGRAPHIC DATA:** 1. Candidate No. ___ 2.Your gender: __ etc.

**(II) OPINION ON VARIOUS ASPECTS IN UNIT**

1. For the purpose of improving this unit, please express your opinion by ticking in the appropriate box, from Item (**a**) to Item **(o),** assuming the statements were yours. SCALE: Strongly disagree **(1)----(5)** strongly agree

| STATEMENTS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| (a) I found the topic dealt with in this unit relevant to Design and Technology | | | | | |
| (b) This unit is very well introduced | | | | | |

2. Any other comments:______________________________

Figure 3.6 A summarized version of the Formative Evaluation Questionnaire (Questionnaire ‘C’)

While Part (I) had sub-components numbered 1 to 5, Part (II) was sub-divided into items 1 and 2. Item (II) 1 had fourteen statements; (a) to (n), where teachers had to indicate their opinions on a 5-point Likert-like scale (Figure 3.6). In Item 2 of Part (II), teachers had a chance to air their views under any comments they could have had. Only the main parts of the questionnaire are represented in Figure 3.6 and for more details, see Appendix 4.



**Implementation and summative evaluation**

Since this stage directly related to the essence of the primary research question introduced in Chapter 1 under Item 1.2, it also had a bearing on the three secondary research questions from a global perspective. At this point, the impact of the course was to be determined.

According to Gronlund and Linn (1990), this stage usually involves setting up the learning environment and delivering instruction, before determining its effect/impact on learners. In this study, all the activities and processes associated with this stage occurred at two levels; during the teaching/learning of MS and during the application of the MS knowledge within MSP. While in the first instance one meant the implementation and evaluation of the relevant instructional materials after development, in the latter one meant the implementation or application and evaluation of the scientific ideas and concepts (knowledge gained from the MS course) in solving specific practical problems encountered during the MSP course.

As recommended by Ally (1997) and Gronlund and Linn (1990), implementation of the instructional materials holistically, required the preparation of both material and human resources. Apart from the learning environment being organized appropriately to include all the necessary equipment, the relevant human resources were also put in place and equipped with the necessary qualifications, particularly for MS where some of the teachers from Intake 1 were staff developed as resource persons, well before Intake 2 joined the department.

Being aware of the fact that the outcome of summative evaluation in this study, like in any other similar context, could be a consequence of several factors, making it difficult to sort out whether a sub-optimal outcome could be due, for example, to poor materials, poor teaching or poor training of teachers, I took special care during the design of the relevant evaluation instruments. This was mainly because I intended to gain deeper insights into the influence of the different aspects of the instructional package on the teachers involved. In fact, this is exactly how the teacher's activities should be considered and evaluated when engaging in D&T (Buchanan, 1998). Reiterating this observation, Buchanan (1998:57) thus qualifies his argument by focusing on 'design' as a function within D&T:

> --- an excellent preparation for a productive and satisfying life. When properly understood and studied, design provides a powerful connective link with many bodies of knowledge. Design integrates knowledge from many other disciplines and makes that knowledge effective in practical life.

However, although teachers were observed physically working in workshops, manipulating tools and materials, the main challenge remained being the need to determine the exact manner in which they were applying their knowledge of MS. During these numerous observations, the key discovery was that while one could easily see people working and sweating in workshops, it was not all that easy to certainly confirm that they were effectively using their knowledge without going deeper into the analysis of the nature of the application and the thinking processes behind the observed activities. Therefore, for the purpose of this study, it was also necessary to understand the process by which teachers engaged in decision making at various levels during their practical activities, especially in the workshops. Basically, this was out of the realization that observing people simply working was one thing and making sense of their activities was another. This then justified further investigations into the matter by other means besides mere observations. And, this is how interviews and content evaluation of the design folios compiled by teachers came in.

Summative evaluation, immediately after implementation, was designed to determine whether the instructional materials had been effective, in improving teachers' performance from a professional point of view. While 'formative evaluation' was conducted to improve the instructional materials before implementation, 'summative evaluation' was conducted to enable the Department of Technical Education at the University of Zimbabwe to decide on whether to continue using the instructional/learning materials or not. Unlike under formative evaluation where only Questionnaire 'C' was used, this stage (summative evaluation) involved a wider variety of instruments, mechanisms and approaches which apart from questionnaires 'A2' (at post-test level) and 'D', also involved interview schedules (for cohorts 1 and 2). In addition there were observations during class and workshop activities, followed by the content analysis/evaluation of design folio as noted in this chapter and in Chapter 4. The scope of activities at this stage, given the variety of instruments, mechanisms and approaches reflects the nature of the evaluation undertaken at two main levels. On the one hand, the first was by means of questionnaires 'D' and 'A2' on completion of the MS course, in addition to observations during lectures in MS. On the other hand, the second level was by means of Questionnaire 'A2', observations during workshop activities, interviews (cohorts 1 and 2) and content analysis/evaluation of design folios on completion of the MSP course.

***Summative evaluation questionnaire*** *(Questionnaire 'D')*

Completed by the 40 serving teachers from Intake 2, this questionnaire was used for the summative evaluation of the materials after implementation and it was designed to gather data specifically in line with Stage 7 of the model in Figure 2.2.

Like Questionnaire 'C', this questionnaire also consisted of two main parts; (I) and (II). However, although Part (I) still asked for the same demographic data, Part (II) was slightly different in that it asked for opinions on the whole modular program instead of going unit by unit. This Part had components (a) to (o) asking teachers to indicate their opinions on specific issues relating to the whole instructional program using a 5-point Likert-like scale. While Figure 3.7 shows the main components, Appendix 5 shows more details of this questionnaire. In Item 2 of Part (II), like in Questionnaire 'C' teachers had a chance to air their views by way of comments.

**Summative Evaluation Questionnaire** (Questionnaire 'D')

**(I) DEMOGRAPHIC DATA**: 1. Candidate No. _____ 2. Your gender: _____etc.

**(II) OPINIONS ON VARIOUS ASPECTS IN Module/Program/Course**

1. For the purpose of improving the whole module/course, please express your opinion by ticking in the appropriate box, from item (**a**) to (**n**) assuming the statements were yours. SCALE: Strongly disagree **(1) ------------ (5)** strongly agree

| **STATEMENTS** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| (a) This whole module is relevant for teaching D&Technology at 'A' Level | | | | | |
| (b) The time (60 hours) allowed for this course is adequate | | | | | |

2. Any other comments: ____________________________.

**Figure 3.7** A summarized version of the Summative Evaluation Questionnaire (Questionnaire 'D')

***Interview guides***

Most of the data gathered during the pilot stages of this study (leading to the design and development of the instructional materials) except for those from the check-list, were collected by means of questionnaires. However, a lot of the quantitative data generated this way resulted in information short of depth and detail to really meet the expectations of the 7th stage of the model in Figure 2.2. For example, on the 5-point Likert-like scale, where two teachers ticked in the box under '5', indicating that they were 'strongly agreed' to a particular statement, one would wonder as to the exact depth in the intensity of their degree of agreement as individuals. In fact, one would wonder whether the '5' in one case would in reality mean exactly the same with the '5' in the other case. Such questions were very difficult to address within the scope of questionnaires. It was therefore necessary to conduct follow-up interviews with sub-samples of the respondents in order to provide meaningful additional data to help make sense out of the data obtained through questionnaires. This was another case where triangulation became necessary. In most cases, the value of '5' was clarified and qualified through explanations and descriptions. This is why the latter part of the main study; particularly the third and forth phases, depended on qualitative methods involving a lot of interviews, document evaluation and analysis (of folios) and video filming (to cover observations). The idea was to identify specific traits of performance, knowledge and cognitive/practical skills confirming specific responses.



According to Patton (1990:132), qualitative data put flesh on the bones of quantitative results, thereby bringing the results to life through in-depth case elaboration. By implication, this metaphor or analogy seems to suggest that quantitative data comprise a kind of skeleton that only comes to life with more information that is in this case, likened to flesh covering the bones of the skeleton, thereby becoming more functional. In other words, qualitative data add value to quantitative results. At this point, Gall and associates (Gall, Borg & Gall, 1996) are in agreement with Patton (1990), maintaining the same assertion.

After the preparatory phases of this study, several questions immerged and answers were still required. Some of the questions were: What did respondents (teachers) really mean when they made specific indications on respective questionnaire items? What elaborations could respondents provide in order to clarify specific responses? How could the various dimensions of analysis fit together as a whole from the perspective of respondents? These were some of the issues that had to be addressed during the later phases of the main study. There was definitely a need to demystify the cloud over these questions and related issues.

Initially, I had planned to have only one cohort of interviews (Cohort '1') following the pre/post-tests with Questionnaire 'A2'. However, after a preliminary analysis of the information from interviews under this cohort and when teachers were preparing for a practical examination in MSP, it occurred to me that I needed to have another lot of interviews (Cohort '2'). To be on the safe side and given the nature of this study, requiring a lot of triangulation, the idea was to have as much information as was possible. It was better to have too much information than to have too little at the end of the day.

Cohort '1' Interview Guide (Application of MS under MSP)

This schedule had two main components, (A) and (B). While (A) had 12 items simply seeking demographic data, (B) had 6 major items asking teachers to indicate the following:



- relationship between what they had learnt in MS and what they were currently learning in MSP
- whether they were finding a chance/chances to apply what they had learnt in MS, in their learning of MSP (Where possible, they were expected to give evidence)
- whether they were experiencing any problems trying to apply their knowledge of MS in their learning of MSP
- how they saw themselves assisting pupils in their learning of D&T at the end of their courses in MS and MSP
- what problems they anticipated back in schools trying to implement MS and MSP (They were also expected to give possible solutions to given problems)

Appendix 7 shows more details of this guide.

Cohort '2' Interview Guide (Usefulness of MS during the practical examination)

Like Cohort '1' Interview Guide, this one also had Part (A) seeking demographic data. However, instead of having only two parts, (A) and (B), this guide had (C) in addition. Parts (B) and (C) were actually like two interview guides in one schedule. While (B) was for the pre-practical examination interviews, (C) was for the post-practical examination.

On the one hand, before the examination, in Part (B) of the guide, teachers were specifically asked to provide information about their views on the following issues, adding up to how they related the MS and MSP courses in their learning:

- their level of preparedness for the on-coming examination
- whether they saw MS and MSP being reflective of each other during the examination. (There was need for evidence of the situation on the ground).
- the extent to which they found their knowledge of MS being useful or applicable during the examination. (Examples and reasons were also required)

On the other hand, in Part (C) providing information about their views on the same issue as in (B), this time after the examination, the same teachers had to indicate the following with examples, explanations and reasons:

- extent to which they felt satisfied with their performance during the examination
- how well prepared they had felt for the examination
- whether they had found their MS and MSP courses reflective of each other during the examination.
- whether they had found their knowledge of MS useful/applicable during the examination.

Appendix 8 shows more details of this guide.

***Observation schedule for class activities during lectures under MS***

Although no instrument was originally designed for observing class activities during lectures, this later became necessary after discovering the problems associated with video filming which had been taken as the main tool for data collection. Details of these problems have been described in sections 3.4 and 3.5 in this chapter. In view of these problems, it then became necessary to urgently design the instrument illustrated in Figure 3.8. This instrument became very important as a guide for note-taking after the termination of video filming.

| NATURE OF DATA e.g. | ORIGINAL REPRESENTATION OF DETAILS AS NOTED |
|---|---|
| - Question | |
| - Answer | |
| - Comment | |
| - Explanation | |

**NOTE:** The item given under nature of data are only examples, for the sake of space

**Figure 3.8** A summarized version of the observation schedule for class activities during lectures.



The idea behind this instrument was to capture and describe relevant data at the appropriate moment, going by the categories identified under the 'Nature of Data'. These categories were the main areas of focus during observations. Under these categories, one was searching for any clues suggesting the learner being knowledgeable in terms of MS. Such clues were expected to manifest within the given categories, which were also used to guide data collection and analysis as explained in sections 3.4 and 3.5.

For data from the little video filming and from the notes manually compiled during lectures, the mechanism in Figure 3.14 was later devised for the purpose of analysis.

***Observation schedule for practical activities in workshops during MSP***

A situation similar to the one noted above, under 'observation of class activities' existed here. Video filming could not cover adequate hours of workshop activities and a mechanism to capture details by hand was devised in the form of the instrument summarized in Figure 3.9. In order to be clear about the nature of observations, the activities that teachers engaged in had to be placed into specific categories under the left hand column as shown in Figure 3.9, starting with group work' and ending with 'turning on the lathe'. These were identified as some of the activities that teachers would be found actively engaged in. At every point of observation, relevant data had to be described within appropriate rows under the right hand column. For example, if one was drilling, focus would be placed upon issues like adjustment of drilling speed according to the nature of the material one would be working on. Again the categories given here were used to guide data collection and analysis as explained in sections 3.4 and 3.5.

| **NATURE OF OBSERVATION** | **DESCRIPTION OF DATA IN FOCUS** (Relevant details) |
|---|---|
| - Group work | |
| - Application of material | |
| - Drilling | |
| - Milling | |
| - Turning on lathe, etc. | |

**Note**: The cases presented in this figure are only examples for the sake of space



**Figure 3.9** A summarized version of the observation schedule for practical activities in workshops

Like with the observation of lectures during MS (where data were analysed through the mechanism in Figure 3.14), data from the little video filming and manual notes from workshop activities under MSP, were later analysed through the mechanism in Figure 3.15.

***Folio evaluation and analysis schedule***

In the Zimbabwean context and according to the 2002 version of the 'A' Level D&T Syllabus, the term 'design folio' refers to a collection of A3 or A2 sheets of cartridge paper written on one side and bound together into a folder. Apart from being written upon, the sheets also contain sketches and working drawing for specific products/project work. This definition of the design folio appears very much in line with Norman, Riley, Urry and Whittaker's (1990) description of the same document, which they assert was originally adapted from a term referring to a large sheet of cartridge paper folded into two or four pages, written on one face each. This is the document later defined by Garratt (1995) as a collect of design sheets in form of a 'logbook'. In this study, this was then the document, record book/journal teachers were expected to compile for each design project, thereby allowing them to trek record their activities (practical and theoretical), going by the design process, culminating in the seven stages/sections represented in Figure 3.10.

| FOLIOS ↓ | STAGE 1 (Section 1) | STAGE 2 (Section 2) | STAGE 3 (Section 3) | STAGE 4 (Section 4) | STAGE 5 (Section 5) | STAGE 6 (Section 6) | STAGE 7 (Section 7) | Total Scores |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| ↓ | | | | | | | | |
| 36 | | | | | | | | |

**Figure 3.10** Skeleton of the tool used to evaluate and analyse data collected from the 36 selected design folios



Given the quantity of the material in the 36 design folios that were to be evaluated and analyzed, there was need to device a tool that would enable one to capture and analyze all the relevant and appropriate data for the purpose of this study. This is where the instrument in Figure 3.10 was used. The idea was to focus on the notes, sketches and records in every section of a given folio and identify any aspects in the form of ideas, arguments and decision making processes influenced by perceptions, understanding and knowledge of MS and D&T. A typical example here could be a case where one would be trying to choose a particular material from among many, for a specific application in problem solving. Figure 3.18 show details on how this instrument was used.

Stages 1 to 7 in Figure 3.10 stand for stages in the version of the 'design process' adopted for the purpose of this study. It is also these same stages that teachers adapted into sections in their design folios. These stages became the basis for scrutiny of the folios, going as follows: Problem situation for design, Design brief and specifications, Investigation and market research, Possible solutions, the Chosen solution, Realization (Path analysis and routing) and Evaluation.

***Questionnaire 'A2'*** *(Learner Analysis of Intake 2 by Pre- and Post-Testing)*

Lastly, as already indicated at the beginning of this sub-section, at post-test level this questionnaire became applicable for the summative evaluation of the whole study, especially after MSP. This is mainly because the questionnaire was basically targeted at addressing the primary research question at the heart of this study, going as follows: 'What effect would a specially designed, developed and implemented Material Science (MS) course have on serving teachers in terms of their perceptions, understandings and knowledge regarding content in MS and instructional practice in D&T?'. For more details on this question and the related secondary questions, refer to sections 1.2 and 1.3 in Chapter 1.

Figure 3.3 and Appendix 3 show details of Questionnaire 'A2'

### *3.3.4 Addressing and dealing with issues of validity and reliability*



Given the nature and scope of this study, the task of establishing validity and reliability was problematic. Although both paradigms, the quantitative and the qualitative were involved, the latter emerged and appeared more dominant as already indicated in Section 3.2. It is the extent to which this study went qualitative that made it a tricky business to establish validity and reliability at various levels. There were so many qualitative mechanisms for purposes of triangulation as already noted. Fears of these complications were not baseless. For example, Tesch (1990) confirms that it is far more complicated to establish the validity and reliability of qualitative data than the quantitative. My personal experience in this study confirmed this observation. According to Tesch (1990), it is far easier to establish reliability and validity in quantitative data than in the qualitative. However, the issue has always been debatable and that debate rages on (Yin, 1999).

'Validity' and 'reliability' are very important concepts in both quantitative and qualitative research, where Cohen, Manion and Morrisson (2003) have described them as being multi-faceted in nature. There are many different types of validity and reliability and there are several ways in which they can be addressed, depending on the focus of study. In this study, there was no way one could imagine the complete eradication of all threats to validity and reliability. However, the intention was to attenuate the effects of these threats by paying special attention to issues of validity and reliability while at the same time relating to these concepts throughout. And, given the multiplicity of the different types of validity and reliability, particular attention was paid to pertinent issues relating to specific activities, where a check list, interviews, observations, questionnaires, content evaluation (of folios) and instructional materials were used.

By the nature of investigations, much was going to depend on the perspectives I was going to have on most of my results and findings, resulting in high chances of being biased. Typical examples of such perspectives were mainly from my views of teaching and learning where I believed in: progressive learning being active rather passive, thereby promoting active learner participation; learning activities being sources of motivation for learners, particularly intrinsically; learning being meaningful rather than being rote in nature in order to achieve meaningful results; providing learners with opportunities to practice new skills in order to apply them successfully in new situations, and corrective measures being provided in order for learners not to repeat mistakes. These views were actually part of the philosophy guiding the development of the instructional materials at the core of this study. Accordingly, given this background, it was necessary to take advantage of the independent views and opinions of other researchers and practitioners.



There were several cases where other people saw things (issues) differently and much clearer than me: for example, my three project promoters, the technician who helped with the interviews, two colleagues (lecturers) in the Department of Technical Education at the University of Zimbabwe, nine resource persons who helped with the implementation of the instructional materials and even colleagues (fellow researchers) in the GRASSMATE Program who helped with the proof reading and discussion of several of my instruments (especially questionnaires and interview guides). Basically, it was the cross-pollination of ideas, coming through the various views and opinions from all these people that helped to reduce obvious threats to validity and reliability, particularly in the instruments. This is an attempt to describe, explain and clarify the measures that were taken to check on personal perceptions over several issues; thereby avoiding being misled or misinformed by my own beliefs and opinions on what I was hearing, seeing and receiving at various levels. I needed to be certain that I was seeing, hearing and making sense out of a reasonably true representation of the reality in given situations.

**The place of validity and reliability in quantitative and qualitative research, as applicable in this study**

While in quantitative research, 'validity' and 'reliability' apply to the design and use of instruments in educational research and other spheres, in qualitative (naturalistic) research, they apply more to the observations researchers make and to the responses they receive during interviews. In both cases, the ultimate destination is data analysis, leading to specific results and findings. According to Fraenkel and Wallen (1996), a fundamental concern in qualitative research revolves around the degree of confidence researchers can place in what they have seen or heard. As already pointed out, the challenge in this study was to make sure that I was not easily misled by what I was hearing, seeing and even receiving in questionnaires. My main worry was the danger of asking questions in such a way that they would sound suggestive of the answers I wanted to hear; especially in questionnaires and interview schedules where I had to watch my language. During observations I was worried about false impressions from stage managed activities and I had to watch out for scenes where actions were designed and intended to have me seeing what the actors thought I wanted to see, especially during workshop activities! And, during the course of this study, there were several cases where my fears were confirmed. This is why in the end, I resorted to casual observations; sometimes taking notes secretly, particularly off or after sessions. However, from a professional point of view, I had to check on whether this approach was not ethically against the principles of fair play, and what gave me confidence in the end was the fact that the information I was gathering was not in any way sensitive, for example, either politically or morally. The idea was to get a realistic picture of the situation, which was also ethically important.



From my basic knowledge of research methods, I was also aware that validity refers to the usefulness, meaningfulness, and appropriateness of the inferences we as researchers make based on the data we collect, while reliability refers to the consistency of these inferences over time or after repetitive cycles or phases of data collection and analysis. In all this, to a great extent, my conscience became my own master as I checked with various views from literature.

**Content and ecological validity in the checklist and instructional materials**

The checklist was very instrumental in identifying content for the instructional materials. After consulting Cohen, Manion and Morrisson (2003), I opined that the checklist had to be valid if the instructional materials were going to be valid in terms of content. I tried to have the checklist as comprehensive as possible in order to be an effective tool for comparing the three relevant syllabi as indicated under Sub-section 3.3.3 of this chapter. This helped to ensure that the materials were reasonably rich in the coverage of relevant and appropriate areas. In addition, the process of trial running the materials and formatively evaluating them was another way of enhancing the validity and reliability of these materials.

Since there was no way everything in the domain of Materials Science (MS) could be covered, there was need for a reasonably representative sample of the materials, where the task was to help teachers acquire relevant and appropriate knowledge. 'Ecological validity' became an issue. While in quantitative (positivist) research variables are frequently isolated, controlled and manipulated in contrived or designed settings, in qualitative (naturalistic) research a fundamental premise is that the researcher deliberately avoids manipulation of variables and/or conditions in order for research activities to occur naturally (Cohen, Manion and Morrison, 2003). These two perspectives were considered important although the latter took a slightly upper hand. While a few variables were isolated, controlled and manipulated, particularly during data collection where timing was a form of control, having the study designed and implemented within the context of an existing programme without any form of manipulation or adjustment of the programme was a move considered naturalistic. This was deliberately designed to promote 'ecological validity'. As much as possible the environment was kept natural and realistic where teachers operated as usual, within existing time tables. Where extra time was spent, it was done just like they would have done even without any research. There was no room for one to do something they would not have normally done. Even the assessment mechanism was maintained within the usual guidelines of the University of Zimbabwe, without any manipulation whatsoever. Following Brock-Utne's (1996) advice, the idea was to give an accurate portrayal of the existing social situation in its own terms, going by the natural settings. A typical example here was the way MS was related to MSP. This relationship was not established for the purpose of this study, but was maintained and went as usual. According to Brock-Utne (1996:617) and Cohen, Manion and Morrison (2000), ecological validity is particularly important in education where it helps to chart the direction that policies follow within a system. This is exactly how I wanted this study to go, following an ongoing programme and its activities within an existing policy framework on education. Morgan (1988) closely relates this (regarding validity) to what he identifies as an immerging notion of 'cultural validity'. In this study, the intention was to shape research activities so that they would be appropriate to the culture of the researched (participants); who in this case were teachers. Cultural validity applied throughout this study; from planning, implementation, up to dissemination. One had to be sensitive to participants' cultures within their given circumstances. This is the orientation that influenced the nature of ethics observed at various levels in this study.

**Validity and reliability in questionnaires**

Being aware of the magnitude of problems associated with postal questionnaires, the four questionnaires used in this study were all distributed and completed there and then, resulting in a 100% return rate in all cases. Although there were problems associated with this approach (like having to wait while respondents completed the questionnaires), these did not amount to anything close to the problems I would have experienced had I used the postal approach, especially those relating to the high rate of non-return questionnaires.

Since respondents were not obliged to give their names, the high level of anonymity promoted and encouraged greater honesty and reliability in the responses. The approach was also more economical than interviews in terms of time and money.

According to Cohen, Manion and Morrison (2003), questionnaires may lack coverage or authenticity if they consist only of closed items. To go around this problem, I therefore incorporated a few items where teachers could openly and freely give comments and suggestions. On the other hand, I was also aware of the danger of having only open ended items in a questionnaire where the main problem would have been a situation where respondents might have been unwilling to write their answers for one reason or another.

For increased validity and reliability, all the questionnaires used in this study were pilot run with teachers of Woodwork and Metalwork outside the B.Ed programme before final administration. These teachers were from all over the country, attending a seminar in Harare. This helped to refine contents and wording before deciding on the length of the questionnaires.

**Validity and reliability in interviews**

Intensive interviews were designed to check on the accuracy of the information obtained through questionnaires. However, although interviews were in this case being used to check on the validity and reliability of questionnaires, there was also a need to ensure their suitability for that purpose. Ensuring their validity and reliability was another challenge in itself. This confirmed Cohen, Manion and Morrison's (2003) assertions regarding various studies where they report numerous problems relating to this issue. In this study, lack of anonymity raised fears of possible bias at various levels during interviews.

According to Fielding and Fielding (1986: 11-12) and Denscombe (1995), possible sources of bias include; characteristics of the interviewer, characteristics of the respondent, and the substantive content of the questions. Biases from such sources include: the attitudes, opinions, and expressions of the interviewer; a tendency by the interviewer to see the respondent in her/his own image; a tendency by the interviewer to seek answers that support her/his preconceived ideas/notions; misconceptions on the part of the interviewer of what the respondent is saying and misunderstandings on the part of the respondent of what is being asked. Scheurich (1995) alleges that interviewers and interviewees bring their own, often unconscious experiential and/or biographical baggage into the interview situation. Eradication of such problems appears impossible as pointed out by Hughes (1976), who argues that because interviews are interpersonal, humans interacting with humans, it is inevitable that the researcher/interviewer will always have some influence on the interviewee and, thereby on the data. According to Scheurich (1995), issues at the heart of these problems also embrace 'transference' and 'counter-transference', rooted in psychoanalysis.

In transference, interviewees project onto the interviewer their feelings, fears, desires, needs and attitudes that derive from their own experiences. In counter-transference the process is reversed. All these assertions seem to suggest that interviewer neutrality is a myth or a chimera (to use Denscombe's (1995) terminology). This is what I discovered in this study. The intention was not really to eliminate the effects of all forms of bias but to minimize them as much as possible through appropriate measures. Some of these measures included: designing highly structured interviews with the same format, sequence of words and questions for each respondent; using the same interviewer for all interviews, thereby minimizing the effects of individual differences; embarking on a training programme for the interviewer who needed to learn about the dangers of altering factors like wording and sequence of questions among others (also had to learn about the importance of positive rapport and how to avoid biased probing); making an effort to have all interviewees understanding all the questions in the same way (not easy though); carefully piloting the interviews with teachers outside the B.Ed programme, and trying to strike a balance between open and closed questions. Most of these measures were adopted from Silverman (1993).

In addition to the measures outlined above, all interviews were tape recorded in order to have them played-back as many times as was necessary. Both interviewer and interviewee (s) were invited to some of the sessions where they would either confirm or refute what they might have said earlier. These conference-like discussions or consultations were necessary, particularly where I doubted the clarity of some statements and claims. This helped to clear the data of possible and obvious distortions resulting from such problems and tendencies as Fraenkel and Wallen (1996) would term 'selective forgetting'. This phenomenon refers to the tendency by respondents to claim one thing today and another tomorrow about the same issue, only to claim having forgotten what they might have said previously. The problem usually becomes worse when one has to cross-check the validity and reliability of a long account of responses. This is where the same respondent would be found choosing what to forget and what to remember, depending on the situation at hand. Effectively, this means one would choose to forget when it is an advantage for them and vice-versa when it is a disadvantage. A typical example of this tendency is usually found in police investigations, where witnesses are usually accused of defeating the course of justice. In educational research without even thinking of the issue of crime, there have also been cases where respondents have been found to be hiding the truth for one reason or another. In this study, although the information that was being sought was not that sensitive, there were a few cases where I suspected, for one reason or another, respondents were making false claims and hiding the truth. This problem was mainly encountered on issues relating to how well teachers felt familiar with the D&T approach in teaching. For example, after claiming to have applied the approach effectively in their teaching, the same respondents would later turn around and claim to be totally ignorant of the approach. This did not make sense by any form of reasoning and logic.



Interviewing the same individuals more than once, as was the case with pre- and post-practical examination interviews also helped to cross-check specific issues before drawing conclusions. For example, Fraenkel and Wallen (1996:462) assert that, inconsistencies over time in what the same individual reports may suggest that s/he is an unreliable informant. In this study, such cases were very remote and isolated. Although there was/were one or two suspicious cases, the magnitude of such suspicions was not adequate to warrant or justify dismissal of the concerned informants from the group of reliable sources.

**Validity and reliability in observations**

From Cohen, Manion and Morrison (2003), I learnt of two relevant questions raising worries about the validity and reliability of observation based investigations. Firstly, worries about the subjective and idiosyncratic nature of the participant observation study are to do with its external validity. For example, how do we know that the results of this one particular study are applicable to similar situations? Secondly, problems about the observer's judgements, fearing the effect of his/her close involvement in the group relate to the internal validity of the method. For example, how do we know that the results of a given piece of research represent the real thing or the genuine product?

To address some of the relevant issues raised here, Cohen, Manion and Morrison (2000) suggest that stringent measures should be taken during sampling in order to check on the representativeness of the events being observed. After considering several possible sampling techniques that included: quota sampling, convenience sampling, dimensional sampling, snowball sampling and purposive sampling, I settled for the last technique which I thought served the purpose of this study appropriately, given the nature of investigations at hand. This was mainly to ensure the external validity of the study.

According to Morrison (1993) and Lincoln and Guba (1985), apart from external validity, participant observation also has to be rigorous in its internal validity checks. In this study, I became aware of several possible threats to internal validity and reliability. These included the following: exploring the present, researcher may be unaware of important antecedent events; informants may be unrepresentative of the sample in the study; presence of the observer may bring about different behaviours (reactivity and ecological validity), and the researcher might 'go native', becoming too attached to the group to see it sufficiently dispassionately. And, to address some of these problems, I took Denzin's (1997) suggestion about the triangulation of data sources and methodologies. This is why it became necessary in this study to engage a variety of instruments and techniques for data collection. For example, most data from observations were corroborated and verified through interviews and document analysis of design folios. In fact, I was of the opinion that where a conclusion was going to be based on data from several and/or different methods and instruments, its (the conclusion) validity would thereby be enhanced. Even the idea of following both paradigms; qualitative and quantitative, as already observed early in this section, was part of such triangulation from a methodological perspective.

In terms of general procedures regarding checking and enhancing validity and reliability, I also embarked on the following, among many other possibilities:

- Checking what one informant would say about an issue against what another would say about the same issue. I opined discrepancies in descriptions and explanations would be an indication of the data being invalid or suspicious in terms of truth.
- Describing in detail, the contexts in which questions were asked and situations in which activities were observed. In this case a little of the video recording also helped to capture selected moments for reference purposes. After some time, original contexts and situations are almost impossible to visualize and let alone, recreate (Patton, 1990). Under such circumstances, claims and even allegation would be very difficult, if not impossible to substantiate, confirm or refute. In some cases, such problems are likely to jeopardize the validity/reliability of evidence, especially where one would be trying to convince an audience of people who were not at the scene, particularly in crime and other related cases.
- Drawing conclusions based on preliminary findings within the field in order to modify and improve on data collection as the study progressed. A good example here was a case where I suddenly decided and quickly devised pre- and post practical examination interviews with teachers after listening to what they were saying during the pre-planned general interview. I took advantage of Patton's (1990) words of wisdom, supported by Robson (1993) advising researchers to take advantage of the opportunities for data collection arising from the field. This was a typical case of one acting on immediate and/or preliminary findings and conclusions within the rigours of active field work.



While the idea was not to claim that these measures and procedures were water-tight in ensuring and/or enhancing validity and reliability in this study, it was reasonable to think and hope that they made an impression on one's faith and confidence in the activities that were conducted under the circumstances this study offered. For example, one could still find weaknesses in the fact that, the findings made here were mainly from one specific group of teachers in a particular context and space in time within a situation where their views and levels of performance might also have been affected or influenced by factors beyond the scope and control of this study.

This section has served to introduce to the issue of 'methodology', concentrating on general procedures and preparations. The main idea has been to describe and explain the general approach, research design, participants, sample selection and instrumentation. Given the scope of this study and for the sake of clarity, it has not been possible to deal with all methodological issues in this one section. Therefore, it is now time to move on to Section 3.4 where issues relating to data collection have addressed.

## 3.4 DATA COLLECTION PROCEDURES

The purpose of this section is to describe and explain the process of data collection in line with the preparations described in Section 3.3 and in keeping with the seven stages adopted from Ally's (1997) instructional design model presented in Figure 2.2, operationalized in Figure 3.1, and going as follows:

- Learner analysis
- Content identification
- Delivery technology selection
- Specification of instructional and learning strategies
- Development of evaluation instruments
- Formative evaluation of the instructional materials
- Implementation and summative evaluation



Going by the preparations in Section 3.3 and given the task at hand, several instruments and mechanisms were prepared for the purpose of data collection. In order to address all research questions, correct preparations were needed in terms of appropriate instruments, mechanisms and approaches. The idea was then to ensure the collection of correct, relevant and appropriate data through correct and appropriate application of the relevant instruments and mechanisms. Wrong application of well prepared instruments and mechanisms does not yield any meaningful results in any situation (Patton, 2002).

Therefore, all instruments and mechanisms prepared as explained in Section 3.3 needed to be applied correctly.

### *3.4.1 Learner analysis*

Information was gathered using questionnaires 'A' and 'A2', in line with the first and second secondary research questions going as follows:

- What perceptions of specific aspects of Design and Technology, as an approach, do teachers hold?
- What knowledge/understanding of specific concepts in Material Science do teachers hold in relation to the teaching and learning of Design and Technology?

Taking two out of the three secondary research questions, 'learner analysis' was one of the major and central issues in this study. Being one of the seven stages in Ally's (1997) instructional design model it also guided the design, development and production of the instructional materials as displayed in Figure 3.1. This is why in Section 3.3 above; it was argued that, answers obtained here had a lot to do with the rest of the steps in the model. In fact, this stage had a bearing on the overall impression of the materials that went into the instructional resource package.

Since this study was about determining the effect of a specific package of instructional materials on a particular group of teachers, in terms of their perception, understanding and knowledge regarding content in MS and instructional practice in D&T, it was important to know and understand the kind of teacher (learner) involved. And, as suggested by Ally (1997), there was a need to identify the following about the learners: characteristics, preferences, motivation (implying needs), level (e.g. qualifications), present level of expertise and all the other related factors. This was the information obtained through questionnaires 'A' and 'A2'.

**Learner analysis questionnaire** (Questionnaire 'A')

Used during the early stages of this study to gather part of the data used for the preparatory or planning phase of the instructional package, this questionnaire (Figure3.2 and Appendix 2) was distributed among the 45 serving teachers under the first intake (Intake 1). These teachers happened to be the whole cohort from this particular intake and as already observed they were information rich. The mechanism for selection was left open where teachers volunteered to participate. This was done on the 11th of March after the university had opened for the first semester on the 25th of February, 2002. All the teachers completed the questionnaire at the same time and they took between 25 and 30 minutes.

**Questionnaire 'A2'** (learner analysis of Intake 2 by pre- and post-testing)

Being the other instrument designed to deal with the issue of learner analysis, this questionnaire (Figure 3.3 and Appendix 3) was distributed among the 40 serving teachers in Intake 2. Teachers completed this questionnaire three times; initially, as a pre-test on 3rd of March 2004 after the university had opened on the 23rd of February and later, on two occasions; on the 24th of June 2004 after the course in MS and lastly on the on 17th of December 2004 soon after the MSP course. The pre-test was conducted the same week the MS course commenced. Respondents took between 35 and 50 minutes to complete the questionnaire during the pre-test. On the other hand, both post-tests were much quicker with teachers taking between 25 and 30 minutes.

Although the original plan was to run Questionnaire 'A2' only twice; before and after MS, to determine the impact of the course on the perceptions and knowledge/understanding and of teachers by comparing their status on these factors before and after the course, the third run of the questionnaire (post-MSP) later became necessary. This followed new interests emerging during observations and interviews. There was need to go slightly further and check on what more value in terms experience, could have been added by the application of MS in MSP. The main interest at this stage was to have a glimpse of how the three profiles of scores appeared in order to have an idea of the value that could have been added by the MSP course. It was hoped this would be reflected by the variations in the perceptions and knowledge/understanding of teachers at various stages and on various items as outlined in parts (B), (C) and (D) of the questionnaire across the board. However as I was planning the third round of data collect with Questionnaire 'A2' I was aware of the possible danger of the hawthorne and halo effects adversely affecting and threatening my findings at this stage. The prolonged administration of this questionnaire meant continuity of treatment that was likely to result in teachers giving answers they might have thought I wanted hear. I therefore decided to watch out for this possibility and took measures to vary my approaches to data collection.

### *3.4.2 Content identification*

The Syllabi Check-list and Questionnaire 'A' were used to source appropriate data for the identification of content to meet the professional needs of teachers.

As already pointed out in Section 3.3, the information obtained with the Syllabi Check-list was very useful in determining what content items to include in the proposed MS course as well as in the whole design of the instructional materials. Such information enabled one to take into account the previous and current experiences of teachers from their background teaching Woodwork and Metalwork at 'O' Level.

The check-list (Appendix 1) was completed very early in this study in consultation with the serving teachers in Intake 1 during class discussions, thereby charting the way forward by providing the relevant information that was required for the whole project to take off.

From Questionnaire 'A', parts (B), (C) and (D) were applicable in the identification of content as indicated in Section 3.3. Therefore, in this section the process of data collection presented under 'learner analysis' also applied for this stage.

### *3.4.3 Delivery technology selection*

No other instruments were used to secure data here apart from those that were applicable for the first two stages ('Learner analysis' and 'Content identification') where the Syllabi Check-list and Questionnaire 'A' were used. The descriptions of the data collection procedures presented under the first two stages were therefore also applicable for this stage. What happened here also depended on what happened under 'Learner analysis' and 'Content identification'. However, in addition to the data collected earlier, more data were secured through Part (F) of Questionnaire 'A' (Figure 3.3 and Appendix 2) where teachers had to air their views on issues considered to be 'anticipated logistical and practical problems'. This is exactly how the instructional resource package used in this study came about as explained under Section 3.3. There is then no need to repeat the descriptions already made under 'Learner analysis' and 'Content identification'.

### *3.4.4 Specification of instructional and learning strategies*

This was another stage that did not require an independent set of instruments although there was a need to gain an insight into the business of teaching and learning in relation to specific, pertinent activities manifesting in the instructional materials. By design, the instructional and learning strategies generated under this stage were incorporated into the instructional resource package (Figure 3.5 and Appendix 6).



Just like for 'Delivery technology selection', the data collected under 'Learner analysis' and 'Content identification' through the syllabi check-list and Questionnaire 'A' were also applicable; resulting in the data collection procedures already presented in relation to these instruments also being relevant at this stage.

### *3.4.5 Development of evaluation instruments*

Being one of the three purely preparatory stages covered in this study, according to Ally's (1997) instructional design model, no data were collected apart from consulting and learning from literature as explained in Chapter 2. Consultation of literature became instrumental in the design and development of all the evaluation instruments.

### *3.4.6 Formative evaluation of the instructional materials*

The process involved trial running the instructional materials in order to revise and improve them. Questionnaire (C) was used for the purpose.

**Piloting the instructional materials**

Teachers who eventually participated as resource persons during the teaching of MS with Intake 2 were selected through their indication of willingness, where Part (E) of Questionnaire 'A' asked them to make such an indication. Out of 45 respondents, 27 indicated an interest. With the help of two colleagues (lecturers in the department), these 27 volunteers were assigned a topic each from the MS course outline (Figure 3.5) on which they prepared lesson plans, following their own format and style. Teachers who later qualified as resource persons used some of these lesson plans in their teaching, with a few modifications and improvements. Developing lesson plans was not a big problem since these were qualified 'O' Level teachers. They also had to include relevant lesson notes on the topics they were dealing with before the plans were graded using the criteria in Figure 3.11.



Although the original intention was to select only those who scored above 50% and leave out those below, all teachers scored above 50% and another mechanism had to be put in place, in order to remain with only 10 who were required. Marks ranged between 53 and 81% in the following profile; **53** (1), **66** (2), **57** (3), **70** (4), **71** (5), **75** (6), **60** (7), **63** (8), **61** (9), **74** (10), **77** (11), **76** (12), **57** (13), **54** (14), **53** (15), **55** (16), **81** (17), **84** (18), **79** (19), **78** (20), **73** (21), **54** (22), **72** (23), **73** (24), **65** (25), **53** (26) and **67** (27). From a total of 1807 marks, the average was 66.9%. Participants in this exercise were not identified by their actual names or official student numbers. They were simply identified as numbers 1 to 27, seen in brackets against the scores in bold. Given this profile, clearly overtaking the original plan, the new mechanism was to short-list all those who scored 70% and above, resulting in a group of 13 being considered for further development through a specially designed crash program. This involved peer-group teaching, where teachers delivered lessons to their colleagues using revised versions of their lesson plans.

Presenters were assessed using criteria similar to those usually used for observing and assessing trainee teachers on teaching practice adapted from the University of Zimbabwe and the University of Concordia in Canada (Figure 3.12). While the document from the University of Zimbabwe was a simple hand-out of guide-lines (mainly for lecturers) comprising less than 10 pages, the one from Concordia was actually a book of 72 pages, authored by Schmid and Weinberg (1988) and designed to guide the practices of lecturers, students, cooperating teachers and school heads.

Although I, as principal researcher, participated in the development of the criteria, I did not partake in the marking, leaving the whole exercise to the discretion of my two colleagues who later produced the mark profiles from which I then short-listed the 13 serving teachers that I ended up with. I avoided marking mainly due to the fear of the negative effects of bias since I had vested interest in the whole exercise.

During preparations for 'peer-group teaching' (a learning activity where student teachers lecture to each other under the supervision of their lecturer/trainer, as part of preparation before the actual teaching practice), each of the 13 teachers who had qualified for training as resource persons was issued with a draft copy of the instructional resource package. Although these teachers had had access to the loose sections of the package from the start, bound copies of the package were only available at this point. It was not possible to secure such copies earlier due to logistical problems, which were mainly reprographic in nature.

| ITEMS OF ASSESSMENT | MARKS | |
|---|---|---|
| | POSSIBLE | SCORED |
| (a) User friendliness of the whole plan | 5 | |
| (b) Relevance of the items of focus in the lesson plan | 10 | |
| (c) Clarity of introduction | 10 | |
| (d) Clarity of aim (s) | 15 | |
| (e) Clarity of objectives | 15 | |
| (f) Relevance and appropriateness of lesson notes to the topic | 15 | |
| (g) Importance and accuracy of the notes (content details) | 25 | |
| (g) Meaningfulness of lesson summary | 5 | |
| **TOTAL** | **100** | |

**Figure 3.11** Criteria for the assessment of lesson plans by prospective resource persons



After this exercise, the materials were greatly improved upon. A lot of constructive criticism and new ideas were shared among all the parties involved and that included me since I was also there to monitor the situation and being the author of the materials. This was a very fruitful experience and some of the sessions and discussions were captured on video in order to keep a record of some of the live observations.

During the class presentations that followed after two weeks, the 13 presenters took turns to lecture. In particular sessions, those who were not lecturing joined the rest of the class in order to learn from each other.

Being a crash program which had to be completed before the arrival of Intake 2 into the department, some of the sessions were conducted on week-ends and after hours, especially group discussions. Most of these extra time activities were initiated by the teachers themselves and this level of interest and commitment was encouraging but, not surprising since teachers had volunteered into the study. However, those sessions that involved assessment of the presenters for qualification as resource persons were conducted at the convenience of my two colleagues whom I asked to act on my behalf, hoping to have a neutral input.

| ITEMS OF ASSESSMENT | MARKS | |
|---|---|---|
| | POSSIBLE | SCORED |
| (a) Level of preparedness | 5 | |
| (b) Relevance of the items of focus in the lesson plan | 10 | |
| (c) Clarity of introduction | 10 | |
| (d) Clarity of aim (s) | 15 | |
| (e) Clarity of objectives | 15 | |
| (f) Relevance and appropriateness of lesson notes to the topic | 15 | |
| (g) Importance and accuracy of the notes (content details) | 25 | |
| (g) Meaningfulness of lesson summary and conclusion | 5 | |
| **TOTAL** | **100** | |

**Figure 3.12** Criteria for the assessment of peer-group teaching



**Completion of the formative evaluation questionnaire** (Questionnaire 'C')

This questionnaire was administered among the 45 serving teachers in Intake 1 during the early developmental stages of the instructional materials, which happened to be the preparatory stages of the whole study. Teachers completed the questionnaire after group discussions where they brain-stormed and discussed the various modular units. This followed the trial running of the materials. They completed this questionnaire for all the units, taking between 10 and 15 minutes on every occasion. Although the materials were in seven units, for administrative purposes in terms of grouping, units 1 and 2 were combined, resulting in six sets of this questionnaire being completed to end up with a total of 270 copies.

### *3.4.7 Implementation and summative evaluation*

Following suggestions by Gronlund and Linn (1990), this stage involved setting up the learning environment and delivering instruction before determining its effect or impact on learners. Activities and processes associated with this stage occurred at two main levels; during the teaching and learning of MS and during the application of MS within the context of MSP. Initially, the process involved implementation and evaluation of the instructional materials after development and later, it was about the implementation or application and evaluation of the knowledge gained from the MS course in the form of scientific ideas and concepts in solving practical problems encountered during MSP.

This is one of the stages from Ally's (1997) instructional design model that directly related to the three secondary research questions addressed in this study. In particular, this stage was in line with the third question: 'To what extent do teachers apply the knowledge gained from the Material Science course in solving practical problems under the Machine Shop Practice course?'

This phase followed the preparation of all the necessary resources where the learning environment (material and human) was made ready for the learning process. Apart from the learning environment being organized appropriately to include all the necessary and relevant equipment, the relevant human resources were also put in place and equipped with the necessary qualifications (For example the 13 resource persons). According to the scope of preparations in Section 3.3, a wide range of instruments and mechanisms were applied at various levels. These included; the instructional package, Questionnaire 'D', interview guides, observation schedules, Folio analysis schedule and Questionnaire 'A2'.

**Teaching of the MS course**

According to the instructional design model in Figure 2.2, this was part of the 7th stage of the process. This is where the 40 teachers in Intake 2 were taught MS by the afore-mentioned resource persons from Intake 1. However, although 13 teachers had qualified, only 9 eventually participated in the actual teaching. The other 4 could not make it since it was after their course of studies and they lived too far from the university; some of them more than 450 kilometres away. Most of those who managed were from around Harare where the university is situated. Those who stayed too far, found it too expensive to travel to Harare.

During implementation of the instructional materials, the 9 resource persons would come and take turns to present lectures on specific days depending on their allocated topics. Although these teachers were assisted on local transport (within Harare) to and from the university, they offered to bring their own food packs. However, there were occasions on which I provided some beverages and drinks.

Apart from teaching and other related activities, implementation of the materials also involved the completion of Questionnaire 'D', as part of summative evaluation.

During teaching, I was available for consultation by both parties; presenters and the audience, particularly on aspects they were not sure of. I was also free to contribute as I saw fit, in order to keep the sessions on course. On several occasions, there were also class discussions on specific issues as requested by the class, especially during the revision of module tests and other related activities.



**Completion of the summative evaluation questionnaire** (Questionnaire 'D) **'**

This questionnaire was completed by the 40 teachers under Intake 2; being part of summative evaluation of the instructional materials. Teachers completed the questionnaire after implementation of the materials, marking the end of MS at the end of June in 2004. The course had commenced in March of 2004. Like with Questionnaire 'C', teachers took between 10 and 15 minutes to complete the questionnaire.

**Observation of class activities during lectures**

These observations were during lectures in MS where the 9 resource persons did most of the teaching although I was there to assist here and there. Only 9 hours of the 60 hour course were captured on video. This was far from the ideal where the original plan was to have at least 50% of the time on video. There were so many logistical problems with implications on cost, especially now when the Zimbabwean Dollar is so weak against major international currencies particularly the American Dollar and the British Pound. Most of the materials were going to be imported using the scarce foreign currency, these days only available on the black market. Today the inflation rate in Zimbabwe is considered the highest in the world; well above 2000 % (BBC-World News, 2007-04-27)! While the original intention was to capture all the sessions on video, it proved too expensive and the idea was modified to include more note-taking (by hand) during some of the sessions. This is where the instrument in Figure 3.8 was used.

Observations on video were useful for reference purposes, especially when it came to the verification of findings later in the study. In such cases, it was possible to play back some of the sessions in order to cross-check specific aspects, particularly in relation to data gathered through other means: questionnaires and interview schedules, for example. Observations under this category were made during implementation of the instructional materials.

**Observation of practical activities in workshops**



All observations here were during workshop activities assigned under the 60 hour MSP course where teachers were expected to put their knowledge and skills of MS into practice in problem solving. Just like MS, MSP also ran for 60 hours. Again, filming time was not adequate. Only 6 hours were possible and the rest of the observations were captured and covered by hand using the instrument in Figure 3.9.

**Conducting interviews**

These were organized in two groups, cohorts ‘1’ and ‘2’. Since these interviews were to do with a course in which I had an interest, I suspected the teachers who happened to be my students were not going to feel free to express their views with me conducting the interviews. My fear was that this was possibly going to lead to unreliable responses, where teachers were going to try and please me by saying what they thought I wanted to hear. I therefore trained the senior technician in the department who was also a holder of the B.Ed degree offered in the department. He was one of those who had been in Intake 1 of the degree program although he had not volunteered to be one of the 9 resource persons. After agreement on remuneration, a crash program was organised in order to equip him with basic skills for conducting interviews as recommended by Patton (1990). The training involved practical skills on how to operate the tape recorder when recording interviews. This was the same man who assisted with most of the video recordings during the observation of class and workshop activities.

Cohort ‘1’ Interviews (Application of MS within MSP)

In all, 18 interviews were conducted during the period 20-10-04 to 30-10-04. The interviews were on a one on one basis where interviewees came one by one into an office located in a very quiet block. They were asked the same questions from Cohort ‘1’ Interview Guide, whose design details have been described in Section 3.3 of this chapter. After giving their demographic data in Part (A) of the guide, teachers were asked six questions in (B). The shortest of these interviews took about 35 minutes, while the longest went for about 45 minutes.

Cohort ‘2’ Interviews (Views on the usefulness of MS during the practical examination)



These interviews were sub-divided into two further categories; Pre-Practical Examination Interviews and Post-Practical Examination Interviews whose guide is in Appendix 8). The examination was in MSP, where teachers were expected to apply their knowledge and understandings of MS. In each category, 11 interviews were conducted with the same teachers, before and after the examination. Cohort ‘2’ Interview Guide was used in this case. The idea was; to determine, compare and contrast their views regarding how they felt about various aspects of the practical examination before and after the examination.

While the pre-examination interviews were during the period 01-11-04 to 10-11-04, post-examination interviews were during the period 01-12-04 to 10-12-04. These dates depended on the examination; a 16 hours event spread over the period 22-11-04 to 26-11-04.

Regarding timing, the shortest interview, which was among the pre-examination group, took about 21 minutes and the longest from the post-examination group was about 36 minutes.

**Content evaluation of design folios**

Data were extracted from the design folios compiled by teachers in Intake 2 during practical activities in MSP. This exercise was expected to provide evidence of the extent to which teachers had applied their knowledge of MS in problem solving situations. It was a kind of examination of the content in order to answer the question: 'To what extent are teachers competent to apply the knowledge/understanding gained from the Material Science course in solving practical problems under the Machine Shop Practice course?'

A total of 36 documents were collected for this evaluation. Although this group had started with 40 members, by the time these documents were collected the group had lost one member who passed away before completing the course. The other three members were not able to submit their folios since they had already taken them home after assessment and examinations in MSP. Their homes were too far from the university, not less than 320 km.



After collecting the folios, the next step was to compile relevant notes during the period 01-01-05 to 30-01-05. Although the original plan was to focus on two practical assignments, eventually only one was considered with the following theme: 'Enhancing Productivity in the Current Land Reform Program in Zimbabwe'. In addressing this topic, teachers were expected to design and make a product of their own choice using various materials, depending on the nature of need. This is where they were expected to apply their knowledge of materials, gained from the MS course. The following key items, adopted from the 'design process' as presented in Syllabi numbers 6035 ('O' Level Woodwork) and 6045 ('O' Level Metalwork) were identified for the purpose of this exercise:

STAGE 1: Problem situation for design
STAGE 2: Design brief and specifications

STAGE 3: Investigation and market research

STAGE 4: Possible solutions

STAGE 5: The chosen solution

STAGE 6: Realization (Path analysis and routing)

STAGE 7: Evaluation

Since these stages were vivid sections in the design folios, they were also adopted for the purpose of compiling the required notes, culminating in a 54 page document entitled, 'Document Analysis of Design Folios' where they (stages) also respectively appeared as sections. It was not necessary to copy all the information from the folios. The idea was to concentrate only on information to do with, or implying issues and phenomena relating to the application of perceptions, understanding and knowledge of MS and D&T within the context of the MSP course. All teachers (represented by their folios) were identified by their candidate numbers and treated as individual 'cases' or 'sites'.

Use of the terms; 'case' and 'site' was adapted from their usual application in areas as disparate as those outlined by Bromley (1986) including; administration, anatomy, anthropology, clinical medicine, counselling, criminology, military studies, psychiatry and social work. Similar outlines of areas where these terms have also been used have been presented by Barrett and Cooperrider (1990), Becher (1990), Chisholm (1990), Krantz (1990), Lincoln and Guba (1985), Miles and Huberman (1984) and Patton (1990 & 2002). According to these authorities, in case studies, a 'case' or 'site' refers to the specific or particular situation, individual, group, organization or whatever it is that we might be interested in. In this study, strategies for dealing with cases in other disciplines provided useful lessons, suggesting solutions to problems with case study methodology, including the thorny one of generalizing from the individual case! During the design of this study as explained in Section 3.3, such lessons proved useful in planning for what Becher (1990), Chisholm (1990) and Robson (1993) have referred to as 'rigorous case studies' like those conducted here, in view of the need to evaluate the work in various design folios.

**Completion of the pre & post-test questionnaire** (Questionnaire 'A2')

At post-test level, this questionnaire became applicable for the summative evaluation of the whole study since it was basically targeted at addressing the primary research question at the heart of this study: 'What effect would a specially designed, developed and implemented Material Science (MS) course have on serving teachers in terms of their perceptions, understanding and knowledge regarding content in MS and instructional practice in D&T?'

Figure 3.4 shows a summarized version of Questionnaire 'A2' while Appendix 3 shows the whole questionnaire in detail.

Completed by the 40 teachers in Intake 2, this instrument was apart from summative evaluation, applicable across the board since at pre-test level, it was also used to analyze the learner. Hence, teachers completed this questionnaire three times; initially, as a pre-test on 3rd of March 2004 after the university had opened on the 23rd of February and later, on two occasions; on the 24th of June 2004 after MS and lastly on the on 17th of December 2004 soon after MSP. The pre-test was conducted the same week the MS course commenced and respondents took between 35 and 50 minutes to complete the questionnaire. Both post-tests were much quicker with teachers taking between 25 and 30 minutes. The final completion of this questionnaire after MSP meant the completion of the whole evaluation process underlying this study. This also meant an arrival at the destination implied by the above-mentioned primary research question, taken from Chapter 1.

## 3.5 DATA ANALYSIS AND STATISTICAL PROCEDURES

The task is now to describe and explain all the procedures followed during data analysis. Focus has remained in keeping with Ally's (1997) model where the following stages have been articulated and illustrated as adapted in Figure 2.2:

- Learner analysis
- Content identification

- Delivery technology selection
- Specification of instructional and learning strategies
- Development of evaluation instruments
- Formative evaluation of the instructional materials
- Implementation and summative evaluation

Therefore, the process of data analysis is described and explained as it went under each of the seven stages and according to specific activities, instruments and mechanisms as designed and determined in Section 3.3. As already indicated, these seven stages were applied in two main ways: first, to guide activities during the preparatory stages and secondly, to guide the whole of this study in view of the primary research question and its three secondary research questions. However, while some of these stages applied on both sides, others applied on one only. For example, the first six were followed during the preparatory phase of the study, the first and second applied on both sides and the seventh stage only applied on addressing the third secondary research question. The first and second secondary research questions were directly in line with 'Learner analysis' and 'Content identification', while the third secondary research question was directly in line with 'Implementation and summative evaluation' (see methodological framework in Figure 3.1).



From this background and looking back to the procedures and preparations in Section 3.3, it is important to note that all the pieces of information that were to be analysed here were those that had been collected through the following instruments and mechanisms:

- The syllabi check-list
- Questionnaires (Most data from the four instruments here were analysed with the aid of Microsoft Excel data bases, and for the sake of identification, all worksheets in specific data bases were assigned names linking them to the respective numbers taken from Microsoft Excel and the relevant sections in given questionnaires)
- Observation schedules (for activities during lectures and in workshops)
- Interviews, and
- The folio evaluation schedule

The package of instructional materials was considered part of the instrumentation in conjunction with the questionnaires, particularly ‘C’ and ‘D’.

Data were analysed in two ways; one guided by the primary research question, touching on all the stages in the instructional design model and the other, according to specific stages at various levels, going by the relevant secondary research questions (also see Figure 3.1).

### *3.5.1 Learner analysis*

Questionnaires ‘A’ and ‘A2’ were used to collect data, going by the preparations in Section 3.3. In both cases, I was expecting to identify the following about the learners: preferences, characteristics, motivation (implying needs), level (e.g. qualifications), present level of expertise, perceptions, knowledge/understanding and their suggestions on specific issues.

**Learner analysis questionnaire** (Questionnaire ‘A’)



A total of 45 copies of this questionnaire (Figure 3.2 and Appendix 2) were completed and all the data were entered into six Microsoft Excel worksheets, representing the following sections of the questionnaire: (A) Demographic Data; (B) Initial Teacher Training; (C) Relating ‘O’ and ‘A’ Level Syllabi; (D) Opinions on items for the Proposed Programme; (E) Indication of Willingness to act as Resource Person and (F) Anticipated Logistical Problems.

Since this questionnaire was also used to collect data for other stages, apart from ‘learner analysis’, it was necessary to isolate relevant sections for this stage. According to Section 3.4, focus was placed on parts (A), (B) and (E), and data were then analysed respectively.

Starting with (A), all pieces of information were entered into **Worksheet 1-(‘A’-A)** of the Microsoft Excel data-base comprising twelve columns of string variables drawn from the demographic data provided by teachers. Specifically, this information comprised of the following aspects: age, gender, college of initial teacher training, period of training, qualification (s) obtained, main subject(s) trained for, subject(s) currently taught, number of years teaching, school where currently teaching, district where school is situated, location of school (rural or urban) and subject of specialization in the B.Ed program. This whole profile of data meant a lot in terms 'learner analysis' and there was need to be as accurate as possible during the analysis, if each learner was to be taken on board. This is the kind of accuracy that the Microsoft Excel data base in **Worksheet 1-('A'-A)** provided culminating in the results and findings in Chapter 4. In this case, while 1 identifies the worksheet number, 'A' stands for the name of questionnaire and –A represents the respective section in the questionnaire. This applied for all questionnaires and their respective sections.

Next, was Part (B) on 'initial teacher training', whose data were entered into **Worksheet 2-('A'-B)** in seven columns [(a) to (g)]. While the rest of the columns were based on a single item, Column (b) had four sub-columns labeled (i) to (iv). All the columns and sub-columns were based on a 5-point Likert-like scale where teachers indicated by ticking in the appropriate box, the extent to which they felt their initial teacher training had prepared them to handle specific aspects of D&T when assisting pupils at 'O' Level. Those aspects were actually the ones labelled (a) to (g) in the worksheet. The data were entered into the worksheet as numerical variables ranging from 1 to 5. For the purpose of analysis, this is where one could calculate mean scores and standard deviations from each column.



Lastly, Part (E) with data entered into **Worksheet 5-('A'-E)**, had items similar to those in Part (D) of the questionnaire, from Item (a) to Item (p) asking teachers to express their views and opinions regarding the inclusion of specific topics in the proposed in-service programme. However, this particular worksheet (**5-'A'-E**) had one additional column where respondents were expected to indicate with a 'YES' or 'NO', whether they were interested in acting as resource persons in the teaching of specific aspects. This item (1) was followed by Item 2 asking teachers to indicate their preferences regarding subject areas if they had shown an interest in acting as resource persons. These preferences were the ones used in the rest of the columns containing exactly the same items as those in Part (D) of the questionnaire except that this time respondents were to show their degree of interest on specific areas. Again, the data were entered into the worksheet as numerical variables ranging from 1 to 5, to enable the calculation of mean scores and standard deviations for the various columns.

**Pre & post-test questionnaire** (Questionnaire 'A2')

According to Figure 3.3, this questionnaire had four main parts; (A), (B), (C) and (D). While part (A) asked for demographic data, the rest, from (B) to (D) were Likert-like scales to determine the perceptions and knowledge/understanding on specific issues and concepts in MS. Teacher were also asked to indicate their levels of confidence in the event of teaching selected items at 'A' Level.

Since this questionnaire was used for pre- and post-testing (Pre-MS, Post-MS and Post-MSP) purposes, the data were processed in three data bases where they were analysed in the same manner. Each data base had four worksheets, going according to the four main parts of the questionnaire. The first worksheet contained string variables drawn from demographic data that had to be analysed qualitatively while the other three worksheets comprised of numerical variables drawn from 5-point Likert-like scales. In each case, data from the last three worksheets were analysed quantitatively to give mean scores and standard deviations. Data were then compared by having items from all data bases compiled in one table, according to specific issues at hand; for example, perceptions and knowledge/understanding of concepts in MS and D&T. The four worksheets in each of the three data bases were named as; **Worksheet 1-('A2'-A)**, **Worksheet 2-('A2'-B)**, **Worksheet 3-('A2'-C)**, **Worksheet 4-('A2'-D)** for the first four where the last of the last four was **Worksheet 12-('A2'-D)**. Like those for Questionnaire 'A', these worksheets were also in Microsoft Excel.

As pointed out in Chapter 1, the three secondary research questions were designed in pursuance of the primary research question. Therefore, address these questions (primary and secondary) fully, and be certain to determine the effect of the MS course on the perceptions and knowledge/understanding of teachers, Questionnaire 'A2' was the central instrument enabling the establishment of these factors at various levels within the professional development of teachers. For example, there was need to establish these factors at entry and exit levels; that is, as teachers came into the programme and as they left.

As already noted under Sub-section 3.4.1, the third run of Questionnaire ‘A2’ (Post-MSP) was never part of the original plan where the intention was simply to compare the scores before and after MS. However, following observations (of class/workshop activities) and interviews, new interests immerged out of the need to check on what value, in terms experience, could have been added by the application of MS under MSP. More specifically, the main interest at this stage was to have a glimpse of how the three profiles of scores appeared in order to have an idea of the value added by the MSP course. It was hoped this would be reflected by the variations in the perceptions and knowledge/understanding of teachers at various stages and on various items as outlined in parts (B), (C) and (D) of the questionnaire. The idea of checking on experiences relating to these factors after MSP was like bringing in a third dimension into the study! And, as the situation unfolded, it turned out that the comparison was not so much between the Pre-MS and Post-MSP experiences as it was between the Post-MS and the Post-MSP experiences. Where it became necessary to compare Pre-MS and Post-MSP experiences, it was mainly via Post-MS. After the MSP course, comparisons between the first two scores were only found relevant in as far as they related to the Post-MSP experiences, on any given issue. It was also interesting to see how the Post-MS experiences related to those after MSP. This is where additional value was expected, in terms of experience. It was the relationship between these two that was expected to usher in new horizons in terms of comparison on each given issue.

***The perceptions of teachers*** on D&T were drawn from their responses to the 15 items in Part (B) of the questionnaire, before and after both, MS and MSP. It was necessary to establish a clear sense of comparison in order to illustrate the difference between and among the responses on the three runs of Questionnaire ‘A2’.

The 15 items in Part (B) of the questionnaire were by design based on specific principles of D&T, both as an approach and as a subject, enshrined in the 2002 version of the ‘A’

Level syllabus as reflected in appendices 1, 3 and 6). These were the same principles/ideas that had been used to guided the design and development of the instructional materials as explained in Sub-section 3.3.3. They included: problem solving, life application, knowledge integration and transfer, hands-on experimentation, no theory specification when engaging pupils in learning activities, minimal laboratory/workshop instruction, and group learning. Given this background, the purpose of Part (B) in Questionnaire 'A2' was to check on the perceptions of teachers regarding these ideas. The extent to which teachers agreed or disagreed with the statements in Part (B) of the questionnaire at pre- or post-test levels helped to indicate their perceptions on specific ideas at a particular point in time.

Although the mean scores and standard deviations drawn on items in Part (B) of the questionnaire were useful in quantitatively showing the various responses by teachers on specific statements or items, this was not enough from a qualitative point of view. Hence, during the analysis of data, efforts were made to gain a deeper understanding of the impression in these values. This was done by means of graphs, scatter plots and comparison/analytical tables, showing the individual responses by all the 40 respondents. During data analysis, these illustrations were generally used to get a visual impression of the responses and to check on the pattern of responses in terms of concentration and density. However, for the sake of this report, all these mechanisms were found giving more or less the same picture, in different ways. Therefore, it was not necessary to illustrate all of them. Graphs and scatter plots were tried and were found to be too cumbersome and uneconomical in terms of space. This left comparison/analytical tables as the best option. They were the most effective/viable mechanism to summarize the high volumes of data involved. One could trace and follow the full pattern of responses by individuals, across the board (Pre-MS, Post-MS and Post-MSP), item by item, as illustrated in tables 3.1 (a) and (b).

**Table 3.1 (a)** Comparison and analysis of individual responses on perceptions, from Pre-MS, Post-MS to Post-MSP, item by item (Numbers 1 to 15 represent the items in Section (B) of Questionnaire 'A2'

| ITEMS ► | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | | 6 | | | 7 | | | 8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST LEVEL ► TEACHER ▼ | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 1 | 5 | 1 | 2 | 4 | 1 | 1 | 4 | 2 | 2 | 4 | 2 | 2 | 4 | 2 | 2 | 5 | 2 | 2 | 5 | 2 | 2 | 3 | 2 | 2 |
| 2 | 4 | 1 | 1 | 3 | 2 | 2 | 4 | 1 | 1 | 3 | 2 | 1 | 4 | 2 | 2 | 4 | 2 | 2 | 4 | 1 | 1 | 4 | 2 | 2 |
| 3 | 5 | 1 | 2 | 3 | 1 | 1 | 5 | 2 | 2 | 4 | 2 | 2 | 3 | 2 | 2 | 4 | 2 | 2 | 4 | 2 | 2 | 3 | 2 | 2 |
| 4 | 5 | 1 | 1 | 3 | 1 | 1 | 4 | 2 | 2 | 4 | 2 | 1 | 3 | 1 | 1 | 5 | 2 | 2 | 3 | 2 | 2 | 4 | 1 | 1 |
| 5 | 4 | 2 | 2 | 3 | 1 | 1 | 3 | 2 | 2 | 4 | 2 | 2 | 4 | 2 | 2 | 4 | 2 | 2 | 4 | 2 | 2 | 3 | 3 | 2 |

**Table 3.1 (b)** Comparison and analysis of individual responses on perceptions, from Pre-MS, Post-MS to Post-MSP, item by item (Numbers 1 to 15 represent the items in Section (B) of Questionnaire 'A2'

| ITEMS ► | 9 | | | 10 | | | 11 | | | 12 | | | 13 | | | 14 | | | 15 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST LEVEL ► TEACHER ▼ | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 1 | 3 | 5 | 5 | 3 | 1 | 1 | 3 | 4 | 4 | 4 | 2 | 2 | 2 | 1 | 1 | 3 | 2 | 1 | 4 | 2 | 2 |
| 2 | 3 | 5 | 5 | 4 | 2 | 2 | 2 | 5 | 5 | 4 | 2 | 2 | 3 | 1 | 1 | 4 | 2 | 2 | 3 | 1 | 2 |
| 3 | 3 | 4 | 4 | 3 | 1 | 1 | 2 | 4 | 4 | 3 | 2 | 2 | 4 | 1 | 1 | 4 | 2 | 1 | 4 | 2 | 2 |
| 4 | 2 | 5 | 5 | 4 | 1 | 1 | 1 | 4 | 4 | 5 | 1 | 1 | 3 | 1 | 1 | 3 | 3 | 2 | 3 | 2 | 1 |
| 5 | 1 | 5 | 5 | 4 | 2 | 2 | 1 | 4 | 4 | 3 | 2 | 2 | 4 | 1 | 1 | 3 | 1 | 1 | 4 | 1 | 1 |



Given the complexities usually associated with issues of perceptions, these tables were useful in interrogating and understanding the impact of perceptual changes and by so doing, enabling one to cross-check the sense behind particular mean scores against the original responses by individuals on specific items. Data were entered for all the 40 respondents across the board. However for the sake of space, only five entries have been picked for illustration. In both tables [3.1 (a) and (b)], letters 'A', 'B' and 'C' respectively stand for the three levels at which Questionnaire 'A2' was distributed among teachers (Pre-MS, Post-MS and Post-MSP).

To determine their ***knowledge/understanding of concepts in MS*** teachers responded to the items in parts (C) and (D) of the questionnaire. These two components [(C) and (D)] were concerned with ‘knowledge of materials’ and ‘level of confidence on given items’, as explained under Sub-section 3.3.3. While Part (C) was the main mechanism designed to determine the level of understanding, responses to Part (D) and performance in the examination were there to cross-check or corroborate the results and findings from Part (C).

Like on the issue of perceptions in Part (B), graphs, scatter plots and comparison tables were also used in a similar manner during the analysis of data under components (C) and (D). For the sake of space, Table 3.2 shows a sample of entries for three out of the forty respondents. However, although comparison/analytical tables have been presented in tables 3.2 (a) and (b), for responses under Part (C), they have been left out for Part (D) since they give a more or less a similar impression, given the issues at stake.

Focusing on Part (C) and using a 5-point Likert-like scale, teachers indicated the extent to which they agreed or disagreed with 30 selected statements, designed to reflect their knowledge of materials (see Appendix 3). These statements were either correct or incorrect and teachers were expected to tell either way and reflect this in their responses.



To indicate their ***level of confidence on teaching selected elements of Material Science at ‘A’ Level***, teachers responded to specific items in Part (D) of Questionnaire ‘A2’. Relevant items were in this case, directly drawn from the course outline of the instructional materials, going according to the same topics as shown in appendices 3 and 6.

**Table 3.2 (Items 1 – 8)** Comparison and analysis of individual responses on knowledge/understanding, from Pre-MS, Post-MS to Post-MSP, item by item (Numbers 1 to 15 represent the items in Section (B) of Questionnaire ‘A2’

| ITEMS ► | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | | 6 | | | 7 | | | 8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST LEVEL ►<br>TEACHER ▼ | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 1 | 4 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 5 | 5 | 5 | 4 | 1 | 1 | 4 | 1 | 1 | 3 | 1 | 1 | 4 | 1 | 1 |
| 2 | 3 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 5 | - | 2 | 2 | 4 | 1 | 1 | 4 | 2 | 2 | 2 | 2 | 2 |
| 3 | 4 | 1 | 1 | 3 | 2 | 2 | 4 | 1 | 1 | 3 | 5 | 5 | 1 | 1 | 1 | 4 | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 1 |

**Table 3.2 (Items 9 - 15)** Comparison and analysis of individual responses on perceptions, from Pre-MS, Post-MS to Post-MSP, item by item

| ITEMS ▶ | 9 | | | 10 | | | 11 | | | 12 | | | 14 | | | 16 | | | 15 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST LEVEL ▶<br>TEACHER ▼ | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 3 | 2 | 1 | 2 | 2 | 1 | 4 | 2 | 2 |
| 2 | 3 | 1 | 1 | 4 | 1 | 1 | 5 | 1 | 1 | 4 | 2 | 2 | 3 | 1 | 1 | 2 | 2 | 2 | 3 | 1 | 1 |
| 3 | 4 | 2 | 2 | 5 | 2 | 2 | 5 | 1 | 1 | 4 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 |

**Table 3.2 (Items 16 - 23)** Comparison and analysis of individual responses on perceptions, from Pre-MS, Post-MS to Post-MSP, item by item

| ITEMS ▶ | 16 | | | 17 | | | 18 | | | 19 | | | 20 | | | 21 | | | 22 | | | 23 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST LEVEL ▶<br>TEACHER ▼ | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 1 | 3 | 1 | 1 | 4 | 5 | 5 | 5 | 4 | 4 | 1 | 4 | 5 | 4 | 1 | 1 | 1 | 5 | 5 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2 | 4 | 2 | 2 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 5 | 5 | 2 | 2 | 2 | 4 | 4 | 4 | 2 | 1 | 1 | 2 | 2 | 1 |
| 3 | 4 | 1 | 1 | 5 | 5 | 5 | 2 | 5 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 4 | 5 | 5 | 4 | 1 | 1 | 3 | 1 | 1 |



**Table 3.2 (Item 24 - 30)** Comparison and analysis of individual responses on perceptions, from Pre-MS, Post-MS to Post-MSP, item by item

| ITEMS ▶ | 24 | | | 25 | | | 26 | | | 27 | | | 28 | | | 29 | | | 30 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST LEVEL ▶<br>TEACHER ▼ | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 1 | 4 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 1 | 1 | 4 | 2 | 2 | 4 | 2 | 2 |
| 2 | 2 | 1 | 1 | 3 | 1 | 1 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 2 | 2 | 4 | 1 | 1 | 2 | 2 | 2 |
| 3 | 2 | 2 | 2 | 4 | 1 | 1 | 3 | 5 | 5 | 2 | 5 | 5 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 1 | 1 |

### *3.5.2 Content identification*

According to the preparations in Section 3.3, the two main instruments under this stage were the Syllabi check-list and Questionnaire 'A' (see figures 3.2 & 3.3 and appendices 1 & 2). The challenge was to identify relevant content to include in the instructional materials for the specific group of teachers in this study. This was in view of their quest for professional development in the face of a new curriculum demanding so much in terms of perceptions, understanding and knowledge, regarding teaching and learning within the context of D&T.

**The check-list**

Completion of this instrument was done by ticking in the appropriate box against specific items/statements. Since the items had been drawn from the 'A' Level D&T syllabus, the idea was to check on whether specific items featured in the Woodwork or Metalwork syllabi. In each case, there was either 'Y' or 'N' (for 'Yes' or 'No' respectively). While the former meant a specific item was present, the latter meant it was absent. This is reflected in Figure 3.13 which shows a summary of how the check-list was completed. Data analysis, in this case, then involved a determination of the patterns immerging from the 'Y' and 'N' ticks featuring under each of the two 'O' Level syllabi as shown in Figure 3.13. Appendix 1 shows more details on the completion of this check-list.

For the sake of clarity, the patterns were divided into three categories taken from the check-list as follows: 'Aims', derived from the overall purpose of the D&T course as coined in the 2002 version of the syllabus; 'Objectives', focusing on specific targets to be achieved as outcomes by the end of the course and 'Content', referring to the actual subject components to be covered in fulfilment of the stated aims and objectives. It was from these patterns that the results and findings presented in Chapter 4 under this instrument were drawn as shown in Figures 4.1.

**CHECH-LIST**: The extent to which the Aims, Objectives, and Content items in the 'A' Level Design and Technology syllabus agree with those in the 'O' Level Metal/Woodwork syllabi.

| ITEMS AND ATTRIBUTES IN 'A' LEVEL SYLLABUS | M/W | | W/W | |
|---|---|---|---|---|
| | Y | N | Y | N |
| A. AIMS:- Students should be encouraged to; | | | | |
| - develop/sustain innovation, creativity and design and technology capability, etc. | √ | | √ | |
| B. OBJECTIVES | | | | |
| (a) Knowledge and Understanding:- Students should demonstrate knowledge and understanding in relation to; | | | | |
| - materials and components for the production of artefacts, etc. | √ | | √ | |
| (b) Design Analysis (generation of ideas & synthesis)- Students should be able to; | | | | |
| - prepare a design brief relating to a situation of need, etc. | | √ | √ | |
| (c) Practical Implementation:- Students should be able to; | | | | |
| - plan and organise the procedure to implement a design proposal, etc. | | √ | √ | |
| C. CONTENT:- Content would include the following: | | | | |
| - The theory of design and technology, etc. | | √ | | √ |



**Figure 3.13** An excerpt from the completed check-list, focusing on examples from the main components

**Learner analysis questionnaire** (Questionnaire 'A')

From this questionnaire, parts (C) and (D) were of particular interest on the issue of 'content identification'. Part (C), was about relating 'O' and 'A' Level syllabi regarding D&T while in (D), one was seeking the opinions of teachers on selected items for the proposed in-service programme. As already indicated under 'learner analysis' above, together with the rest of the parts in this questionnaire, data from parts (C) and (D) were collapsed into a Microsoft Excel data base comprising six worksheets where they respectively occupied sheets 3 and 4.

Part (C) with data in **Worksheet 3-('A'-C)**, had exactly the same items as those in Part (B) entered into **Worksheet 2-('A'-B)** as already indicated under 'learner analysis'. However, the only difference was that, while in **Worksheet 2-('A'-B)**, teachers were being asked to indicate the extent to which they felt their initial teacher training had prepared them to teach the listed aspects at 'O' Level, this time they were to indicate the extent to which the same elements could be considered pre-requisite to 'A' Level D&T.

Part (D) in **Worksheet 4-('A'-D)**, had sixteen main columns labelled (a) to (p) and again like in parts (B), (C) and (E), Column (b) had four sub-columns, (i) to (iv). This data base consisted of items on which teachers had to express their opinions regarding their inclusion in the proposed in-service programme. Information from parts ['(C) and (D)] was in addition to what came out of the demographic data drawn from Part (A) of the questionnaire, entered into **Worksheet 1-('A'-A**).

### *3.5.3 Delivery technology selection*



Since decisions on this stage also depended on the outcome of investigations under stages 1 and 2 of the instructional model in Figure 2.2, to do with 'learner analysis' and 'content identification' as already alluded to, the analysis of data under those stages as explained above was also pertinent for this stage. This refers to information collected through the Check list and Questionnaire 'A'. Out of the six components of Questionnaire 'A'; from (A) to (F), the last was particularly interesting. This part only applied here and nowhere else. Teachers were asked to share their views on listed items considered to be 'anticipated logistical and practical problems'. The information went into **Worksheet 6-('A'-F)** as numerical variables, ranging from 1 to 5 and later computed into mean scores and standard deviations in a manner similar to that explained for parts (B), (C), (D) and (E). During the planning stages of this study, it was hoped such data were going to provide a clue of the situation in schools, regarding facilities and material resources available and accessible to teachers. In many ways, this also helped to give an idea of the instructional technology one could depend upon. What came out of the demographic data, also proved useful and was entered into **Worksheet 1-('A'-A)** as already indicated under 'learner analysis' above.

### *3.5.4 Specification of instructional and learning strategies*

Being another preparatory stage that did not require an independent set of instruments, like stage 3 above (Delivery technology selection), what happened here depended on what happened under the preceding stages, in terms of procedures; particularly the first and the second ('Learner analysis' and 'Content identification').

### *3.5.5 Development of evaluation instruments*

This was another stage [after 3rd and 4th from Ally's (1997) model], mainly there for preparatory purposes covered very early in this study. No data were specifically collected for this purpose and therefore there were no data to be specifically analysed. This was simply a necessary and recommended procedural step that had to be covered once a draft of the instructional materials was in existence.



### *3.5.6 Formative evaluation of the instructional materials*

For the 270 copies of the Formative Evaluation Questionnaire (Questionnaire 'C') completed during data collection, one data base was opened for all the units and data were entered into six Microsoft Excel worksheets (**1-'C'** to **6-'C'**) according to respective units. The main component of this questionnaire, which was a 5-Point Likert-like scale, had numerical data quantitatively analysed to obtain mean scores and standard deviations where teachers were to express their opinions on specific items relating to particular units.

### *3.5.7 Implementation and summative evaluation*

As indicated during the description of data collection procedures in Section 3.4, this stage involved setting up the learning environment and delivering instruction before determining its effect or impact on learners. It has also been made clear that activities and processes associated with this stage occurred at two main levels; during the teaching and learning of MS and during the application of MS under MSP, as expected under D&T. The former was about implementation and evaluation of the instructional materials after development, while the latter was about ‘implementation’ in the sense of application and evaluation of the knowledge gained from the MS course (scientific principles, ideas and concepts) in solving specific practical/technical problems encountered during the MSP course.

From the three secondary research questions addressed in this study, this stage specifically related to the third one, going as follows: ‘To what extent do teachers apply the knowledge gained from the Material Science course in solving practical problems under the Machine Shop Practice course?’

A wide range of instruments/mechanisms were employed at various levels, within this stage. These included; the resource package of instructional materials (evaluated through Questionnaire ‘D’), observation schedules (for lecture and workshop activities), interview guides (cohorts 1 & 2), Folio analysis schedule and Questionnaire ‘A2’. Therefore, the idea is to explain how the data collected through these instruments/mechanisms were analysed.



**Summative evaluation questionnaire** (Questionnaire ‘D’)

In terms of design, this questionnaire (Figure 3.7) was similar to Questionnaire ‘C’ (Figure 3.6, used for the formative evaluation of individual units of the instructional materials as explained under Sub-section 3.5.6 above. Questionnaire ‘D’ was completed by the 40 teachers of Intake 2 and was for the summative evaluation of the whole instructional package. Like in Questionnaire ‘C’, the main component of this questionnaire (a 5-point Likert-like scale) had numerical data that was quantitatively analysed to obtain mean scores and standard deviations indicating the opinions of teachers on aspects relating to the whole instructional package. Data from this questionnaire were entered into the same data base with those from Questionnaire 'C' as **Worksheet 7-'D'**, following sheets **1-'C'** to **6-'C'** belonging to Questionnaire 'C'.

**Observation of class activities during lectures**

The MS course designed for the purpose of this study was a 60 hour programme like the rest of the other programmes in the Department of Technical Education at the University of Zimbabwe. For meaningful analysis of the data from observations, the original plan was to video film at least 50% of the lectures in terms of hours. Analysis would then have involved playing back the videos capturing all targeted events and incidents within specific intervals of say 3 minutes, 5 minutes, 10 minutes or so, depending on careful adjustments as determined by the results obtaining from pilot experiences. Had the ideal materialised, the following were going to be some of the targeted incidents;

- every time a member of the class asked a meaningful question relating to the topic under discussion
- every time one answered a scientific question in a scientific manner
- every moment a member made a meaningful comment on an issue relating to the topic under discussion
- every time a member made a meaningful explanation of an issue relating to the topic under discussion



Among many other incidents deserving capturing on a specially designed grid, these four were outstanding. A statement, question, answer, comment or explanation would be considered meaningful if it was sensible, true and scientifically correct, from a MS point of view. Every time an incident would have been considered thus, a tick would have been entered at that very moment according to the timing slot in the grid with the aid of a stop watch. This was supposed to be the ideal situation had enough filming hours of the lectures been achieved. Unfortunately, the ideal did not happen in terms of filming time. Only 9 hours of the possible 60 hours (lecture time) were covered.

Now, since the ideal had not been possible, the plan had to be changed. Instead of analysing data using the intended grid, the last resort was to use the data for reference purposes like cross-checking/confirming results and findings from questionnaires, interview schedules and content evaluation of design folios. Where necessary, replays of particular events were run until the right details were captured to confirm a particular incident or case. Figure 3.14 shows this mechanism, which is actually an observation schedule. This time, it was a schedule and not a grid.

Although it was not possible to capture all lectures on video, the mechanism in Figure 3.14 was very useful for the verification of data from other sources, especially those from interview schedules and questionnaires, as already indicated. This schedule was flexible enough to also accommodate hand written notes from direct observations (without video).

| **NOD** | **MOTIVI** | **Data Captured Directly** | **Nature of Understanding** |
|---|---|---|---|
| - Statement | | | |
| - Question | | | |
| - Answer | | | |
| - Comment | | | |
| - Explanation | | | |

**Key**: NOD – Nature of Data MOTIVI – Moment of Timing on Video



**Figure 3.14** Mechanism for capturing and analysing data from observations during lectures as taken from video clips and manual notes

Data from hand written notes were also used to capture the most critical observations in terms of the reality of cases where individuals behaved naturally without acting in front of the camera. Among such cases were those where one would make a comment in their home language, for example Shona or Ndebele instead of English.

**Observation of practical activities in workshops**

Just like the data captured during class activities, the data captured in the 6 hours that were possible here were also useful for purposes of verifying information relating to issues arising from workshop activities. The idea was to check and take note of the times or moments during which actors worked in groups, as individuals, consulting and explaining issues (especially workshop processes) to each other. There was also need to capture specific practical activities actors spent time on, for example drilling on the pillar drill and turning on the lathe. In such cases, one (the observer) would check on the manner in which particular actors manipulated both tools and materials. A typical example could be one making the necessary speed adjustments either on the lathe or drilling machine, as required or recommended for a specific type of material. Figure 3.15 shows details of the mechanism that was used to capture all such cases within specific time slots on the video clips. Even where direct observations were made, the same mechanism was used for making hand written notes with minor adjustments, for example, skipping the column on 'moment in video clip'. However, the column on 'explanation of case and nature of knowledge or understanding was maintained either way.



| **Case** | **Moment in clip** | **Duration of activity** | **Explanation of case & nature of knowledge/understanding displayed in the application of MS** (Details illustrating such understanding) |
|---|---|---|---|
| - Group activity | | | |
| - Drilling | | | |
| - Milling | | | |
| - Turning on lathe, etc. | | | |

__Note__: The cases presented in this figure are only examples

**Figure 3.15** Mechanism used to capture and analyze data from observations during workshop activities as taken from video clips and written notes

**Interviews**

Being in two cohorts; '1' and '2', data from these interviews were analysed in two groups. However, the latter were further sub-divided into two more groups; 'Pre-practical examination interviews' and 'Post-practical examination interviews'. Specific details on how data from these interviews were analysed are provided below.

Cohort '1' Interviews

All the 18 interviews under this cohort were captured on ten 60 minute audio tapes. Analysis of these interviews commenced with transcripts where all the details were extracted and recorded in writing. The whole process of transcribing, categorizing and trying to make sense out of the data took a lot of time; long hours and days of playing and careful listening where tapes were played and replayed, again and again resulting in a 40 page document. Words of the interviewer and interviewees were captured and taken word for word in an effort to be as original as possible. The message in every word, phrase and sentence was taken seriously in order to be as close as possible to the picture in every case. All these details were captured in 18 transcripts, culminating in 40 pages, which for the sake of space could not be included in this report. However, Appendix 9 shows a typical (original) transcript for Case Number 17, taken as a sample for this lot of interviews.

Further analysis of all the transcripts, highlighting and focusing on relevant details of interest, depending on specific issues led to the development of various matrices, from question to question. The first matrix (Appendix 10) contained demographic data from all the 18 interviewees and appendices 11 to 16 show matrices containing summaries of responses on issues respectively relating to the following: (i) Relationship between MS and MSP; (ii) Chance(s) to apply MS in MSP; (iii) Evidence of MS in practical activities during MSP; (iv) Problem(s) encountered in efforts to apply MS in MSP; (v) Foreseen application of MS and MSP in teaching, and (vi) Anticipated problems in trying to implement MS and MSP back in respective schools. Analysis of data in these matrices was done by focusing on individual interviewees from the first matrix (Appendix 10) to the last in Appendix 16, going case by case and issue by issue. This meant going across all the issues and down, according to cases, resulted in specific patterns leading to the respective results and findings reported in Chapter 4 in line with the third secondary research question.

<u>Cohort '2' Interviews</u>

Being in two sub-groups (pre-practical examination and post-practical examination), these interviews resulted in two independent documents of transcripts where the former had 14 pages while the latter had 17. In both cases, the transcripts were then summarised into matrices that went according to the respective guides for the two sub-groups of interviews. For details on these matrices, see appendices 17 to 25. While appendices 17 to 21 were for the pre-practical examination interviews, 22 to 25 were for the post-practical group. For the purpose of analysis, both groups were considered at the same time and collectively.

As already indicated in Section 3.4, the same 11 teachers were interviewed in both sets of interviews and therefore, demographic data were only taken for the pre-practical examination interviews as shown in Appendix 17, and not for those in the post-practical examination category. The same data applied for both groups. Both sets of interviews were entered into the same data base where data for specific interviewees were carefully coordinated and synchronized across the board from Appendix 17 up to 25, issue by issue. In this case, one could trace the responses of individual interviewees from the pre-practical examination to the post-practical examination interviews, resulting in specific patterns for particular respondents as reflected by the results and findings in Chapter 4.

Appendix 26 shows an example of a transcript from one pre-practical examination interview while Appendix 27 shows one from the post-practical examination interviews. In both of these appendices, the same individual (Interviewee No. 1) was interviewed before and after the examination. In this case, the purpose of presenting data from one interviewee was to demonstrate whatever changes could have occurred between the two phases; pre-examination and post-examination experiences of this individual as an example for the group of 11. It was possible to read such changes by closely tracing and tracking data from individual interviewees from the transcripts summarized in various matrices, case by case and according to specific issues as already indicated. Information from all the matrices was placed in one composite data base/spread sheet for the sake of clarity during data analysis.

**Content evaluation of design folios**

After compiling notes from the 36 design folios culminating in the 54 page document alluded to in Section 3.4, the next step was to make sense out of the notes. Therefore, the task in this section is to explain how the data were analysed in order to make sense. The process involved going through all the notes and identifying issues, phenomena and specific points at which one could have evidence of teachers having applied their knowledge of MS in solving practical problems during MSP, as expected under the D&T approach. This was in line with the third secondary research question; 'To what extent are teachers competent to apply the knowledge/understanding gained from the Material Science course in solving practical problems under the Machine Shop Practice course?'



Although the information from the folios was summarized in an effort to only focus on relevant details, a lot of effort was made to try and have it as much as possible 'word for word' in all cases. Therefore, for the sake of clarity, all the normal print on all cases or sites in the 54 page document was for information taken 'word for word' and all that in italics was for my comments, explanations and interpretations. All serving teachers were identified by their candidate numbers and treated as separate 'cases' or 'sites'.

Since data collection from the design folios had been guided by the seven stages of the 'design process' adopted from syllabi 6045 ('O' Level Metalwork) and 6035 ('O' Level Woodwork), it was found logical to follow the same stages during data analysis. Focus was therefore placed upon the following stages: **1** Problem situation for design; **2** Design brief and specifications; **3** Investigation and market research; **4** Possible solutions; **5** Chosen solution; **6** Realization (Path analysis and routing), and **7** Evaluation. It was within these stages, also developed into respective sections in the design folio that one searched for evidence of statements containing reasoning, choices and decision-making implying traits of perceptions and understanding appropriately supported by knowledge of MS.

The 54-page document comprising notes from the 36 design folios was closely studied according to the criteria in Table 3.3, where numbers **1** to **7** represented the above mentioned stages of the design process, effectively translating into respective sections of the design folio. The excerpt in Figures 3.16 illustrates how these sections were represented as numbers in bold within the notes from the various folios.

Statements (i) to (vi) in Table 3.3 are not really about issues totally independent of each other. They are basically about one checking for evidence of teachers having applied their knowledge of MS in solving practical/technical problems as in MSP. In many ways, the application of knowledge in this case also reflected a lot on one's perceptions and understanding in relation to the given phenomena in focus. However, experience showed that although the main purpose of analysis was to locate and identify evidence of the application of MS in the design folios, the sense of focus tended to differ across the seven sections. Therefore statements (i) to (vi) in Table 3.3 helped to differentiate the sense of focus across the respective sections from **1** to **7**. For example, while in sections **1** and **2**, the idea was simply to check on the clarity of statements relating the 'Problem situation for design', 'Design brief and specifications', in sections **3**, **4**, **5**, **6** and **7** teachers were expected to make informed decisions, explanations and arguments relating to the selection and justification of possible solutions, materials and tools in given contexts. It was within these contexts that the application of MS was to be demonstrated.

**Table 3.3** Matrix representing criteria for identifying and locating traits of MS in the design folios

| STATEMENTS | CODE | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| i) Clarity of relevant details as informed by knowledge of MS | Det-Cla | X | X | | | X | | |
| ii) Clues implying application of MS in specific statements | Ap-Clu | | X | X | X | X | | |
| iii) Evidence of choices and decision making being guided by knowledge of MS | Ch&D-m | | | X | X | X | X | X |
| iv) Appropriate use of MS knowledge in explanations/descriptions of processes & procedures | Pro-Exp | | X | | | X | X | |
| v) Evidence of Material Science in highlighting and focusing on relevant issues | MS-Iss | | | | | X | X | X |
| vi) Evidence of appropriate use or application of materials in design or problem solving | Mat-App | | | | | | X | X |

<u>**Key for Codes**</u>: (i) **Det-Cla** = Detail Clarity (ii) **Ap-Clu** = Application clues (iii) **Ch&D-m** = Choices and decisions (iv) **Pro-Exp** = Process explanation (v) **MS-Iss** = Material Science issues (vi) **Mat-App** = Material application.



For the sake of clarity, the codes indicated from (i) to (vi) in Table 3.3 were marked throughout a hard copy of the 54-page document containing notes from the 36 design folios. For every folio, there was need to identify this evidence by means of such markings, and Figure 3.18 shows a summary of how this evidence was then transformed and reduced into a tabular record where every tick means a trait of MS according to the criteria in Table 3.3. For the sake of space, only folios 1 to 8 are represented in Figure 3.17 and patterns for the rest of the folios (9 to 36) are presented in Appendix 28. These patterns were an important indication of the extent to which teachers had applied their knowledge of MS in solving practical problems at various levels during MSP. This was also a way of corroborating what teachers had claimed in questionnaires and during interviews regarding their application of MS in MSP. Such application was expected in the various forms presented in Table 3.3.

**FOLIO CASE NUMBER R032262W**

1. Need to shell groundnuts
2. Design and make a groundnut sheller that will enhance quick processing of - groundnuts. *Specifications: - cost effective – efficient – durable – user and environmental friendly – easy to maintain and service – maximum level of ergonomics.
3. * Materials: - Locally available (e.g. metal) – strong enough to withstand deformation from; tensile, compressive and shear forces. * Mechanisms: Stay mechanism to allow for movement – rotary for shelling. * Factor Analysis: Light weight – ergonomics (comfortably height. * Safety: Safe finish.
4. (i) Shells as operated by one person (ii) With a perforated plate, has a crush-pad moving back and forth (iii) Pounding in compartments (iv) Pedal method (v) Flange mechanism.
5. * Flange Method of Shelling: Rubber flanges to avoid breaking (crushing) the nuts – handle for shelling machine dowelled to allow for movement – curved base or tray to allow movement of nuts to the centre and out for collection – stay to allow for movement of tray.
6. (i) Measuring, marking out and cutting (ii) shaping and forming (iii) drilling holes or perforations in tray (iv) Welding and sanding (v) Sanding (vi) Assembling (vi) Appropriate finishing.
7. (a) Function: Mock-up indicates that the actual prototype will function effectively. (b) Aesthetics: Components shaped appropriately (c) Ergonomics: Comfortable height for a range of users. This is likely to result in comfort during use. (d) Balance and proportion: Generally, dimensions on mock-up indicate that prototype is likely to be reasonably well in balance and proportional. However, it appears prototype will perform better with a slightly larger base. (e) Safety Features: Rounding off of sharp edges and corners on various components is likely to be effective on prototype.

**Figure 3.16** An excerpt of the notes from (Folio-Case Number R032262W) Note: These notes have been highly compressed for the sake of space and numbers **1** to **7** stand for the sections in the folio

Although all the 36 folios had evidence of one form or another as outlined in Table 3.3 the issue was to determine the extent to which the knowledge of MS was applied at various level within the various folios, by the individual teachers. This was not easy and several approaches were tried. The evidence was there within the data, but how to make sense out of the data remained a problem. It was only after several trials that a reasonable approach emerged comprising two routes. While one route involved following the profiles in individual folios (representing individual teachers) across all sections (from 1 to 7), the other was about following and going per section, from folio 1 up to folio 36 (Figure 3.17 and Appendix 28 for the sense of the whole orientation). However, there was need to summarize and have an over-view of this information in order to make sense and meaning out of it, for the benefit of this study. It was also necessary to establish a system or systems of interpreting the data.

In view of the two routes highlighted above, the idea was to come up with ways that could be used to put the data in specific units for the purpose of interpretation. This resulted in two scales designed according to the nature of the data at hand. In both cases, the scale was based on the range of scores as taken from Figure 3.17 and Appendix 28.

After determining the sense of both sets of scores, it was then possible to group or categorize them into the following levels in ascending order: Very Low; Low; Moderate; High and Very High. This was the sense in which the results and findings reported in Chapter 4 under Item 4.3.3, specifically focusing on design folios were presented in tables 4.13 and 4.14. For the sake of clarity, Rows 1 to 8 here and 9 to 36 in Appendix 28 stand for the number of folios analysed while columns 1 to 7 stand for the stages in the design process translating to the seven sections of the design folio.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total Scores |
|---|---|---|---|---|---|---|---|---|
| 1 | | √√ | √√√√ | | √√ | √√√√√√√√ | √√√√√√√ | 22 |
| 2 | √ | √√√√√√√√ | √√√√√√√√ | √ | √√√√√ | √√√√√√ | √√√√√√√√ | 37 |
| 3 | | √√√ | √ | | √√√ | √√√√√ | √√√√√√√√ | 20 |
| 4 | | √√ | √√√√√ | | √ | √√√√√ | √√√ | 16 |
| 5 | | √√√√ | | | | √√√√√√√ | √√√√√√√√√√√ | 22 |
| 6 | | √√ | | | √√√√√√√ | | √√ | 11 |
| 7 | | √√√ | √ | √√ | | √√√√ | √√√√√√√√√ | 19 |
| 8 | | √√√√√√ | √√√√√√√√√√ | √ | √√ | √√√√√√ | √√√ | 28 |

**Figure 3.17** An excerpt showing how scores were entered for folios 1 to 8. [In this example, every tick stands for an indication (Clue or evidence) of MS having been applied. Appendix 28 contains the rest of the entries covering folios 9 to 36, ]

**Pre & post-test questionnaire** (Questionnaire 'A2')

Apart from being used to gather information for 'learner analysis', as explained under Sub-section 3.5.1, this instrument was also used to gather information on 'implementation and summative evaluation'. Therefore the process of data analysis explained under Sub-section 3.5.1 was also applicable under this sub-section (3.5.7).

## 3.6 A SPECIAL NOTE ON THE APPLICATION OF THE MEAN IN THIS STUDY

Given the nature of data obtained through the Likert-like scale applied in all the four questionnaires used in this study ('A', 'A2', 'C' and 'D'), where the views/opinion of teachers were to be determined over various issues, the mean, being one of the simplest models or mechanisms in descriptive statistics that could be fitted to such data was found adequately suitable and appropriate. According to Field (2000), the 'mean' qualifies to be considered as a model because it represents a summary of data. In this study, it effectively served that purpose in several places; summarising data in order to make meaning.

To check on the extent or degree to which the 'mean' was an accurate representation of the data in the various cases, I used the standard deviation as the measure. Field (2000) asserts that, the smaller the standard deviations (relative to the value of the mean itself), the closer the data points are to the mean and the larger the standard deviations, the more distant the data points are from the mean. While in the former case, the mean would be an accurate representation of the data, it would not be so in the latter. This is what I carefully checked for, across the board in relation to all the cases where the mean was applied. In short, while the 'mean' was considered an effective illustration of the concept of a statistical model summarizing the data, the variance and standard deviation illustrated how the goodness-of-fit of that model could be measured. There were however, a few isolated cases where the standard deviation got so close to the mean, to warrant a cause for concern. Typical examples of this were items (b) (ii) and (b) (iii) in tables 4.1 and 4.2 respectively. It is such concerns that were hopefully addressed through the wide-spread triangulation adopted in this study.

In this chapter the focus has mainly been on the methodological framework, general approach, research design, general preparations, data collection procedures, data analysis/statistical procedure. Given this background, it is now time to move on to

Chapter 4 where the results and findings yielded from all the preparations and procedures described in this study are presented.

# Chapter 4

## RESULTS AND FINDINGS (Expected and Unexpected)

Results and findings are in this chapter categorized into, the preparatory and the main. While the former were drawn from preparatory activities and investigations leading to the production of the resource package of instructional materials at the core of this study, the latter were based on the three secondary research questions comprising the main thrust of the study as illustrated in Figure 3.1. Going by the design of study, both categories fell within the parameters of the following primary research question: 'What effect would a specially designed, developed and implemented Material Science (MS) course have on serving teachers in terms of their perceptions and knowledge/understanding regarding content in MS and instructional practice in D&T?'



Given the sense behind Figure 3.1 and considering the influence of Ally's (1997) instructional design model in this study, the whole process of data analysis explained in Section 3.5 of Chapter 3 had a direct impact on the presentation of results and findings in this chapter, culminating in the conclusions drawn in Chapter 5. According to the Methodological framework in Figure 3.1, the seven stages in Ally's (1997) model applied according to the above mentioned categories; the preparatory and the main. Results and findings therefore went in line with specific stages from the model, respectively depending on the level as shown in Figure 3.1. For example, at the preparatory level, the focus was upon the following stages (1 to 6):

- Learner analysis
- Content identification
- Delivery technology selection
- Specification of instructional and learning strategies
- Development of evaluation instruments; and,
- Formative evaluation of the instructional materials

While stages 1, 2 and 6 required one to gather data, 3, 4 and 5 were simply procedural in the preparation of the instructional materials.

On the other hand, the main level focused upon stages 1 and 7, going as follows:

- Learner analysis; and,
- Implementation and summative evaluation (of the instructional materials)

In this case, 'implementation and summation evaluation' as a stage, was viewed from two perspectives; *implementation and evaluation of the instructional materials within Material Science (MS)* and *application of MS under Machine Shop Practice (MSP)*. According to plan, this part of the study conformed to the pre- and post-test design, where 'leaner analysis' took the former while 'summative evaluation' took the latter.

Although two groups of teachers (separated by intake and not by design) were involved, the teachers were considered more or less the same in terms background and professional needs. Therefore, the instructional materials that were designed and produced with the help of the 45 teachers in Intake 1 (2002-2003) were assumed and proved to be relevant and appropriate for the 40 teachers in Intake 2 (2003-2004).



Given the situation where participants were in two groups, sharing the same background experiences and professional needs, it was necessary to establish the link between them. This is what is presented in Section 4.2, which incidentally also explains the link between the two categories of results and findings; the 'preparatory' and the 'main' in sections 4.1 and 4.3.

## 4.1 THE DESIGN/DEVELOPMENT AND PRODUCTION OF THE INSTRUCTIONAL RESOURCE PACKAGE

Results and findings at this level were derived from data collected through the check-list in Figure 3.4 and Appendix 1 (based on 'O' Level Wood/Metalwork and 'A' Level D&T syllabi), and questionnaires 'A' and 'C'. All activities were mainly in preparation for the major part of the study, based on the three secondary research questions. The idea was to gather as much information as possible in order to design and produce the required instructional resource package. This is where the first six stages from Ally's (1997) instructional design model fitted, in terms of guiding events and activities in this study.

### *4.1.1 Learner analysis (at the preparatory level of the study)*

In order to design, develop and produce relevant and appropriate learning materials for the purpose of this study, there was a need to understand the type and nature of learner the materials were meant for. Specifically, the learners were in this case those 45 teachers belonging to Intake 1, among which Questionnaire 'A' was administered and they responded as explained in Chapter 3. Parts (A), (B) and (E) were of particular interest, where analysis was centred on the following aspects; background of the teachers, level of preparation during initial teacher education/training and an indication of willingness to act as resource-person, in the event of teaching MS.

**Background of the teachers**

Relevant data were drawn from Part (A) of Questionnaire 'A', which had to do with demographic data, where all details relating to the teachers were provided, resulting in the information presented below.



While the youngest member was 26, the oldest was 51 years old from a group of 41 males and 4 females who had gone to the following colleges for initial teacher training in their respective numbers; Belvedere Technical Teachers' College (38), Gweru Teachers' College (6) and Chinhoyi Technical Teachers' College (1). From this group, the earliest trained teacher had gone to college during the period 1973-1975 and the latest had been trained during 1996-1999, where 17 teachers qualified with certificates in education and 28 had diplomas in education. Out of the 45 teachers who completed this questionnaire, none had indicated having taken science related subjects like Physics and Chemistry, which also happen to relate very well with MS. Considering key periods of training in relation to the advent of D&T in Zimbabwe, the majority (39) had trained after 1987, specifically between the years 1988 and 1999. In terms of subjects, while 23 teachers initially qualified to teach Woodwork, 22 were qualified to teach Metalwork at 'O' Level.

Before coming to college they were all teaching the subjects they had trained for, where the least experienced taught for 2 years and the most experienced had been teaching for 28 years. Among the schools these teachers were teaching, 25 were located in urban areas, 19 rural and only one was peri-urban. During the time of study, these teachers were enrolled in the Bachelor of Education degree programme where 23 were studying Wood Technology and Design while 22 were studying Metal Technology and Design.

From this background, one got an idea of the following about the learners' characteristics such as: level (e.g. qualifications), present level of expertise, experience in terms of years in the teaching profession, college of initial teacher training, period of training and location of school where one could have been teaching. Such information was useful in the identification of content for the instructional materials. For example, the fact that none of the teachers had studied subjects like Physics and Chemistry during initial teacher training helped to indicate what aspects to include in the package at foundation level and the knowledge that the majority (39) had trained after the advent of D&T education in Zimbabwe, indicated that they were at least familiar with the concept as an approach, thereby helping to establish the starting point in the materials. These examples show that this was one of the points at which 'learner analysis' related closely to 'content identification', going by Ally's (1997) instructional design model in Figure 2.2.



**Level of preparation during initial teacher education and training**

In Questionnaire 'A', Item 1 of Part (B) teachers were asked to indicate the extent to which they felt their initial teacher education/training had prepared them to deal with specific elements of the existing 'O' Level Wood/Metalwork syllabi when assisting pupils in their learning of D&T. Table 4.1 then shows the responses of teachers on this issue, in respect of specific given areas. According to the 5-point Likert-like scale, going by the respective mean scores and standard deviations, one could determine the way teachers felt about their initial teacher education and training. Specific scores indicated whether they felt adequately prepared or not, to handle specific aspects in terms of teaching at 'O' Level.

Teachers felt happy with their teaching of the Theory of Design and Technology and Graphic Communication. On the rest of the elements, from Material Science, Mechanisms and Motion, Structures, Pneumatics, right down to Hydraulics, teachers were not quite comfortable since most of their responses ranged from 'not at all' prepared, 'not quite' prepared up to a feeling of 'indecision'. However, considering the pattern of responses and ratings on individual items, two dimensions immerged. On the one hand, there were items on which teachers appeared to have a greater degree of consensus in terms of given judgements, while on the other extreme there were items on which they tended to widely differ. Typical examples of the former case were items (a) and (g) where the standard deviation was extremely small, relative to the given mean score. The latter case was exemplified in items (b), (ii), (iii), (iv) and (d) where the ratings spread much further from the mean, thereby indicating widespread disagreements among teachers in their judgements, in view of the issues at hand.

Clearly, the trends in the two extremes explained above had implications for the curriculum package. Given the sense behind the question, teachers were unanimously agreed in their satisfaction with items (a) and (g). There was therefore no need of including them in the package. Instead, it was those aspects where teachers expressed wide-spread dissatisfaction that one needed to seriously consider for inclusion in the package. This included areas where judgements wondered widely in terms of difference, like Item (b) (iii) in Table 4.1, which had to do with 'Materials processing'.

**Table 4.1** An indication of the feelings of teachers regarding levels of preparation during initial teacher education and training as was required by Item (B) 1 of Questionnaire 'A'

**N = 45**

| Item | Mean | SD | Item | Mean | SD |
|---|---|---|---|---|---|
| **(a)** Theory of Design and Technology | 4.29 | 0.87 | **(c)** Mechanisms and Motion | 2.80 | 1.24 |
| **(b)** Material Science | 1.93 | 1.16 | **(d)** Structures (types & designs) | 1.98 | 1.12 |
| **(i)** Evolution & Nature of Materials | 1.91 | 0.92 | **(e)** Pneumatics | 1.82 | 0.83 |
| **(ii)** Materials & Properties | 2.09 | 1.33 | **(f)** Hydraulics | 1.53 | 0.79 |
| **(iii)** Materials Processing | 1.93 | 1.32 | **(g)** Graphic Communication | 4.38 | 0.68 |
| **(iv)** Materials & Process Selection | 2.00 | 1.28 | | | |

**Key:** SD - Standard Deviation

**Indication of willingness to act as resource-person for specific area (s) of interest**



Out of the 45 serving teachers in Intake 1, only one was not interested in acting as a resource person. The rest indicated their willingness. However, asked to indicate elements of preference in the event of one acting as a resource person in the teaching of specific aspects under D&T, even the one who had indicated lack of interest also indicated areas of preference as required by Item (E) 1 of Questionnaire 'A'. Scrutiny of the raw data showed that this individual was among those who indicated a keen interest in participating in the teaching of Item (a), which was about the 'Theory of Design and Technology'. Table 4.2 shows these indications as given by the 45 teachers from Intake 1.

According to Table 4.2, the majority of the teachers were interested in, or rather prepared to teach the 'Theory of Design and Technology' as already indicated. A mean score of **4.84** showed a very high interest on this area. Mean scores of **3.56** and **3.96** respectively for areas (e) Mechanisms and Motion, and (p) Graphic Communication also showed that a reasonably good number of teachers were fairly interested in these areas, almost approaching the range of **4.00**.

With mean scores ranging from **1.71** to **2.33**, teachers were not prepared to handle the rest of the areas and the question was, ‘Why?’ This suggested a close look at the responses to Item (B) 1 of Questionnaire ‘A’, considering its apparent close relationship with Item (E) 1. These items appeared to be triangulating each other.

**Table 4.2** An indication of preferences in the event of one being a resource person as required by Item (E) 1 of Questionnaire ‘A’

**N = 45**

| Item | Mean | SD | Item | Mean | SD |
|---|---|---|---|---|---|
| **(a)** Theory of Design and Technology | 4.84 | 0.42 | **(g)** Thermodynamics | 1.87 | 0.84 |
| **(b)** Materials Science | 1.80 | 1.08 | **(h)** Fluid mechanics | 2.09 | 0.92 |
| **(i)** Evolution and Nature of Materials | 1.76 | 0.98 | **(i)** Electricity and Electronics | 2.33 | 1.38 |
| **(ii)** Materials and their properties | 2.02 | 1.37 | **(j)** Analogue Signal Processing | 1.80 | 0.99 |
| **(iii)** Materials Processing | 1.96 | 1.22 | **(k)** Digital Signal Processing | 1.71 | 0.92 |
| **(iv)** Materials and Process Selection | 1.93 | 1.16 | **(l)** Control Systems | 2.33 | 1.17 |
| **(c)** Structures (types and designs) | 2.29 | 1.20 | **(m)** Pneumatics | 1.80 | 0.81 |
| **(d)** Stress Analysis | 2.13 | 1.16 | **(n)** Hydraulics | 1.71 | 0.73 |
| **(e)** Mechanisms and Motion | 3.56 | 1.83 | **(o)** Computer Control | 2.27 | 1.40 |
| **(f)** Energy and Dynamics | 2.02 | 1.10 | **(p)** Graphic Communication | 3.96 | 0.80 |

**Key:** SD - Standard Deviation

The same areas, highly rated here (in Table 4.2), were also comparatively highly rated in Table 4.1, especially (a) and (g), respectively registering **4.29** and **4.38**. Although element (c) registered a much lower score than the other two in Table 4.1, compared to the score in Table 4.2, the two scores were even more closely related, featuring as **3.80** and **3.56**. In its group, the score of **3.80** for Mechanisms and Motion, despite being below the range of **4.00**, was considered significantly high where the rest of the other elements registered between **1.32** and **2.09**. While Table 4.1 is about teachers expressing their feelings regarding levels of satisfaction with their professional preparation in relation to the teaching of specific aspects of D&T, Table 4.2 is about the same teachers indicating their preferences of areas in the event of teaching.

What is being reflected by the two tables (4.1 and 4.2) was naturally and understandably a case of teachers drawing confidence from their background experience. They felt confident to teach the following areas at ‘O’ Level: Theory of Design and Technology, Graphic Communication and Mechanisms and Motion. The same confidence was expected to persist even at ‘A’ Level. As already implied earlier, given the confidence and satisfaction expressed by teachers, there was no need to give priority to such areas in the curriculum package since teachers logically and justifiably needed help on those areas they lacked confidence in their teaching.

### *4.1.2 Content identification*

The identification of content for the curriculum package became very easy after description of the learner. Demographic data led to the following aspects: relationship between syllabi, areas of interest, foundation for ‘A’ Level D&T and opinions on areas to include in the proposed in-service programme. The intention was to accommodate and/or meet the learners’ needs in terms of professional growth and development.

**Relating the ‘A’ level D&T syllabus to the ‘O’ Level wood/metalwork syllabi**



Appendix 1 shows the completed check-list and from the pattern emerging, the ‘A’ Level D&T Syllabus (2002 version) was found closely related to the two ‘O’ Level syllabi (Woodwork and Metalwork). However, there were slight differences as reflected in Figure 4.1, summarizing data from the completed check-list, going by the various sections therein.

Figures 4.1 shows which of the aspects in the ‘A’ Level D&T syllabus also featured in the other two syllabi by illustrating the levels at which the syllabi respectively agreed or disagreed, regarding Aims, Objectives and Content. Several aims, objectives and content items in the ‘A’ Level syllabus also appeared in both Wood/Metalwork syllabi, thereby effectively illustrating the close relationship between these three syllabi.

Since the course outline for the MS course was drawn from the ‘A’ Level syllabus, these results and findings helped to give a clue to what teachers were already familiar with, and what could have been new to them.

| **TOTAL AIMS IN THE ‘A’ LEVEL SYLLABUS** | **M/W** | | **W/W** | |
|---|---|---|---|---|
| | **Y** | **N** | **Y** | **N** |
| **8** | 6 | 2 | 4 | 4 |
| **TOTAL OBJECTIVES IN THE ‘A’ LEVEL SYLLABUS** | **M/W** | | **W/W** | |
| **(a)** Knowledge and Understanding | **Y** | **N** | **Y** | **N** |
| **4** | 3 | 1 | 3 | 1 |
| **(b)** Design Analysis | | | | |
| **6** | 3 | 3 | 3 | 3 |
| **(c)** Practical Implementation | | | | |
| **4** | 3 | 1 | 2 | 2 |
| **TOTAL CONTENT ITEMS IN THE ‘A’ LEVEL SYLLABUS** | **M/W** | | **WW** | |
| | **Y** | **N** | **Y** | **N** |
| **25** | 12 | 13 | 15 | 10 |

**Figure 4.1** An indication of the extent to which the AIMS, OBJECTIVES and CONTENT in the ‘O’ Level Woodwork and Metalwork syllabi agreed with those in the ‘A’ Level D&T syllabus

## The foundation of ‘A’ level D&T

In the Zimbabwean context, the education system is such that, what happens at ‘O’ Level for most subjects, if not all, is supposed to be the foundation of what later goes on at ‘A’ Level. Therefore, for Design and Technology (D&T), being a technical subject with roots in subjects like Woodwork and Metalwork, it was expected in this study that what happened in Woodwork and Metalwork at ‘O’ Level was going to be a foundation for D&T at ‘A’ Level. Effectively, this meant that what teachers got familiar with at ‘O’ Level regarding the teaching and learning of D&T was going to provide the starting point of their new experiences teaching the subject at ‘A’ Level. This was very important in order to know where we were coming from and where we wanted to go in terms of decision making on what elements to include in the intended instructional materials. Being an intervention course, one really needed to be sure of the point of entry. In the instructional materials, this meant starting from the known and going into the unknown. According to the constructivist view of learning, knowledge about the learners’ level of understanding is crucial for the design of learning activities meeting both the learners’ needs and the challenges relating to differences between learners’ prior understanding and the new insights to be learnt. This justified the need to start with familiar topics at foundation level in this study, before introducing new and more complicated topics.

In this study, the belief was that once the learner’s needs were identified, it was then possible to identify the desired content. The learner was also given the chance [through Section (C) of Questionnaire ‘A’ (Appendix 2)], to play a role in the identification of the content. ‘Content identification’ also meant one being led to the setting of goals and specifying what the learner was going to be able to achieve upon completion of the programme. In this case, the content had to be relevant and appropriate to the given learners, confronted with a new curriculum, demanding new knowledge and understanding. Table 4.3 shows details of findings resulting from the responses of teachers in Part (C) of Questionnaire ‘A’.

**Table 4.3** An indication of whether the proposed course elements could be regarded pre-requisite to the teaching of D&T at 'A' Level as required by Item (C) 1 of Questionnaire 'A'

**N = 45**

| Item | Mean | SD | Item | Mean | SD |
|---|---|---|---|---|---|
| **(a)** Theory of Design and Technology | 4.27 | 0.91 | **(c)** Mechanisms and Motion | 4.31 | 0.91 |
| **(b)** Material Science | 4.22 | 0.85 | **(d)** Structures (types & designs) | 4.16 | 0.95 |
| **(i)** Evolution & Nature of Materials | 4.29 | 0.76 | **(e)** Pneumatics | 3.78 | 1.06 |
| **(ii)** Materials & Properties | 4.27 | 0.81 | **(f)** Hydraulics | 4.04 | 1.04 |
| **(iii)** Materials Processing | 4.13 | 0.76 | **(g)** Graphic Communication | 4.33 | 0.71 |
| **(iv)** Materials & Process Selection | 4.31 | 0.76 | | | |

**Key:** SD - Standard Deviation

In view of the picture obtaining in Table 4.3, one can safely assert that teachers indicated that nearly all the areas; (a) to (g) were pre-requisite to what they were going to encounter, teaching D&T at 'A' Level. It therefore meant that they could see a close relationship between the three syllabi, in terms of progression.



All items except for (e) had mean scores ranging between **4.00** and **4.33**. Even Item (e) which appears to have fallen out of the range, was not very far off. It registered **3.78**, which was very much on the upper limit of **3.00**, almost approaching **4.00**. A close analysis of the raw data showed several responses ranging between scores **3** and **4** on the Likert-like scale. Although a lot of teachers indicated that the syllabi were 'fairly related', several also indicated that the syllabi were 'very much related'. This confirmed and reinforced the findings drawn from the check-list as presented under Sub-section 4.1.1 above. By implication, this meant one could take advantage of the experiences of these teachers in terms of what they already knew about D&T, particularly as an approach and then incorporate that into the materials.

**Teachers indicating priorities and preferences on areas of interest**

Being major players in this study, teachers were given several opportunities to indicate and express their needs and interests regarding professional development. Firstly, such opportunities were provided through those questions resulting in tables 4.1 and 4.2. At this stage, by indicating areas of interest for possible course development, teachers were being given yet another opportunity to make such indications, thereby further contributing towards the identification of content items that had to be included in the instructional materials. According to the design of Questionnaire 'A' (Figure 3.2 and Appendix 2), teachers were able to make such contributions in specific parts and items. Their priorities and preferences in respect of professional needs became evident starting from learner analysis where they showed their areas of strength and weakness from initial teacher training as shown in Table 4.1. In addition, teachers also expressed their views and opinions on areas they wanted to see included in the instructional materials. This was through Item 1 in Component (D) of Questionnaire 'A' (Figure 3.2 and Appendix 2). These opinions were expressed in view of issues relating to importance, relevance and appropriateness in the Zimbabwean context. Indeed, the responses which teachers made here showed that they had special preferences, on what they wanted to see included in an in-service programme, designed for their professional development. Their choices also appeared to indicate areas they found inadequate in terms of preparation from their initial teacher education and training. This is where items (B) 1 and (D) 1 in Questionnaire 'A', somehow related. They were both about for shortfalls reflecting levels of mismatch between teacher preparation and realities in schools.



According to Table 4.4, teachers indicated that the following areas were important and they wanted to see them included in the proposed in-service program; Materials Science and its related components, Structures, Mechanisms, Motion, Electricity, Electronics, Pneumatics and Hydraulics. These important areas had mean scores ranging between **4.1** and **4.8** as shown in Table 4.3. The rest of the areas in the table were considered not so important since they had mean scores ranging between **2.0** and **2.7**.

**Table 4.4** An indication of elements or items to be included in the proposed in-service programme as required by Item (D) 1 of Questionnaire ‘A’

**N = 45**

| Item | Mean | SD | Item | Mean | SD |
|---|---|---|---|---|---|
| **(a)** Theory of Design and Technology | 2.38 | 1.48 | **(g)** Thermodynamics | 2.00 | 1.09 |
| **(b)** Materials Science | 4.60 | 0.58 | **(h)** Fluid Mechanics | 2.11 | 1.07 |
| **(i)** Evolution and Nature of Materials | 4.58 | 0.62 | **(i)** Electricity and Electronics | 4.16 | 0.74 |
| **(ii)** Materials and their Properties | 4.80 | 0.40 | **(j)** Analogue Signal Processing | 2.04 | 1.19 |
| **(iii)** Materials Processing | 4.73 | 0.45 | **(k)** Digital Signal Processing | 2.07 | 1.07 |
| **(iv)** Materials and Process Selection | 4.62 | 0.52 | **(l)** Control Systems | 2.22 | 1.17 |
| **(c)** Structures (types and designs) | 4.07 | 0.62 | **(m)** Pneumatics | 2.47 | 1.20 |
| **(d)** Stress Analysis | 2.20 | 1.12 | **(n)** Hydraulics | 4.11 | 0.78 |
| **(e)** Mechanisms and Motion | 4.29 | 0.69 | **(o)** Computer Control | 2.69 | 1.38 |
| **(f)** Energy and Dynamics | 2.24 | 1.05 | **(p)** Graphic Communication | 2.33 | 1.43 |

**Key:** SD - Standard Deviation



### An insight into the instructional resource package

From all the results and findings so far, the resolve was to choose Material Science (MS) for the design, development and production of an exemplary course out of all the other possible aspects of Design and Technology (D&T). This was in view of the teachers' opinions and preferences on areas to be included in their course of studies, as already reported under Component (D) of Questionnaire ‘A’. In addition to the views of teachers, further investigations involving a comprehensive literature search during the preparatory stages of this study culminated in the identification of specific recommended elements for the intended instructional resource package of the MS course comprising seven units with each unit basically structured as follows:

- Unit Title (referring to the main topic dealt with in a particular unit from 1 to 7)
- Unit Objectives (These were drawn from the overall aims of the package)
- Unit Content:
- Unit Summary
- Practice Activity or Activities

- Group Activity or Activities
- Self-Assessment
- Reflection
- Unit Test

Note: While all the above items featured in all the units, module tests 1 and 2 below only appeared after Unit 7.

MODULE TEST 1 (Units 1-7)
MODULE TEST 2 (Units 1-7)
As indicated in Chapter 3, the two module tests comprised of items drawn from all the units and they were eventually collapsed into the final examination in Appendix 27.

Further investigations resulted in the identification of the following main MS topics under respective units: 1. Three families of engineering materials; 2. Metallic structures; 3. Effects of stress and temperature on simple metal structures; 4. Engineering alloys; 5. Steel, cast iron, ductile and malleable iron; 6. Composite materials, including concrete and wood, and 7. Plastics. Appendix 6 shows a more detailed course outline of the instructional materials.



### *4.1.3 Delivery technology selection*

As a result of the investigations conducted under the first two stages of Ally's (1997) instructional design model (learner analysis and content identification), the package of instructional material at the centre of this study emerged. It was actually part of the technology identified in the form of seven modular units encompassing several activities that included, group work and tests. Relevant teaching aids used in conjunction with the curriculum package included; the chalkboard, overhead projector, power-point projector and also video. The two stages (learner analysis and content identification) were crucial in the selection of the relevant instruction technology. For example, understanding the characteristics of the learner, which included needs, helped in the identification of the relevant content. In turn, these factors led to the selection of the relevant instructional technology. There was no way one could have been able to select appropriate technology for the purpose of this study without understanding the nature of the learner and the content involved.

Apart from the outcome of investigation during ‘learner analysis’ and ‘content identification’ directly helping in the ‘delivery technology selection’ more clues came from Part (F) of Questionnaire ‘A’ on ‘anticipated logistical problems’ (Table 4.5). Some of these problems had implications on the choice of technology for the delivery of content and were taken seriously, culminating in the instructional materials and the associated teaching aids.

**Anticipated logistical problems/difficulties in the teaching of D&T at ‘A’ level**

Table 4.5 shows that teachers, on the one hand, anticipated logistical problems relating to the lack of: relevant literature, relevant equipment, relevant materials (consumables) and support from teachers of other subjects. On the other hand, they did not foresee problems relating to lack of: facilities, time on the time table, and safety.

**Table 4.5** An indication of anticipated logistical problems and difficulties in the teaching and learning of Design and Technology at ‘A’ Level as required by Item (F) 1 of Questionnaire ‘A’

**N = 45**

| Problem | Mean | SD | Problem | Mean | SD |
|---|---|---|---|---|---|
| **(a)** Lack of relevant literature | 4.76 | 0.43 | **(d)** Lack of relevant materials (e.g. wood, metal and plastic) | 4.78 | 0.42 |
| **(b)** Lack of relevant equipment | 4.82 | 0.39 | **(e)** Inadequate time allocation on timetable | 1.49 | 0.55 |
| **(c)** Lack of facilities, esp. laboratories & workshops | 1.78 | 0.64 | **(f)** Lack of support from trs. of other subjects | 4.73 | 0.49 |
| **(g)** Unsafe working conditions | 1.93 | 0.99 | | | |

**Key:** SD - Standard Deviation

Regarding the issue of ‘delivery technology selection’, not all items in Table 4.5 were relevant. It was only those relating to lack of: literature, equipment, facilities and materials that appeared pertinent. The rest related to issues elsewhere, as noted in Chapter 5 under discussion. On the issues outlined here, all the problems anticipated by teachers regarding the situation back in their respective schools helped to give a clue of the circumstances under which they were going to work. Most of those circumstances had implications on the nature of delivery technology for the content at hand, as explained in Chapter 5.

### *4.1.4 Specification of instructional and learning strategies*

These strategies were packaged within the delivery technology and appropriately built into the instructional materials. They were specifically designed for the type of learner involved and the nature of content at hand. In the first place, even the decision to use modular materials divided into specific units was part of the strategies that were applicable in this study. Some of the strategies that were also deliberately embedded into the instructional materials included the following; unit summaries, practice activities, group activities, self-assessment mechanisms, reflection and unit/module tests.

In addition, as already mentioned in Chapter 3, deliberate measures were also taken in order to ensure:



- active rather than passive learning, thereby promoting active learner participation.
- learning activities that would motivate learners in the instructional process.
- meaningful learning rather than rote learning.
- opportunities for learners to practice new skills so as to apply such skills in new situations.
- corrective feedback in order for learners not to repeat mistakes.

These strategies were justified by the need to promote an emancipatory type of education, designed to enhance meaningful/non-alienating forms of 'teaching/learning'. Being part of the philosophy behind the study, they also guided the design/development of the instructional materials. Even the decision to link MS and MSP was motivated by these strategies.

### 4.1.5 Development of evaluation instruments

Like the 3rd and 4th stages above, this stage also depended on the outcome of investigation during the 1st and the 2nd stages of Ally's (1997) instructional design model in Figure 2.2. Results and findings from these early investigations led to the development of several instruments for both formative and summative evaluations. The scope of this study, where both the learner and the materials needed evaluation, justified the variety of instruments used: module tests, the final examination, questionnaires ('C', 'D' and 'A2'), the two interview guides (cohorts 1 & 2) and the two observation schedules (for class and workshop activities). Figures 3.3, 3.6 and 3.7 and appendices 3, 4, 5, 7 and 8 show details of these instruments. Learner achievement in terms of learning and the effectiveness of the materials needed to be determined, hence the variety of instruments.

## 4.2 BUILDING BRIDGES BETWEEN THE PRODUCTION OF THE INSTRUCTIONAL MATERIALS AND THEIR APPLICATION



### 4.2.1 Implementation of the instructional resource package

The instructional materials were formatively evaluated before implementation and summatively evaluated after implementation. Formative evaluation was done with the help of teachers in Intake 1, while implementation and summative evaluation were achieved with those in Intake 2. However, it is perhaps important to note that the summative evaluation of this package was at two main levels: firstly, through Questionnaire 'D' and secondly, through Questionnaire 'A2', interview/observation schedules and folio evaluation. In fact, this whole project was an evaluation study, designed to determine the effect of a particular MS course on the perceptions, understanding and knowledge of a specific group of teachers, regarding content in MS and instructional practice in D&T. Findings on this issue are covered in Section 4.3.

The question of bridging the preparatory and the main findings in this case is explained by the fact that we had two important activities at this point linking the two main samples of participants in this study. The two activities were the formative and the summative evaluations of the instructional materials and the two important groups of participants were the 45 serving teachers belonging to Intake 1 (2002-2003) and the 40 belonging to Intake 2 (2003-2004) of the B.Ed. degree programme. While the former group contributed to this study by participating in the design and development of the materials (including formative evaluation), the latter contributed by participating during the implementation of the materials, culminating in summative evaluation.

### *4.2.2 Formative evaluation of the instructional resource package*

All the findings here were drawn from responses to Questionnaire 'C' (Appendix 4) which was about the content evaluation of various modular units from 1 to 7. Six sets, amounting to a total of 270 copies of this questionnaire were completed and returned by the 45 serving-teachers belonging to Intake 1. The sets were arranged according to the number of units within the instructional resource package as explained in Chapter 3.

Figure 3.5 in Chapter 3, shows a summarized version of Questionnaire 'C'. However, compared to the items/statements in the actual questionnaire, those presented in Table 4.6 have been highly summarized for the sake of space.



**Opinions on the proposed specimen instructional materials**

***Units 1 and 2***

These two units were combined and assigned to one group for logistical reasons. Administratively, Unit 1 was found to be too short to stand on its own and the decision was to present it together with Unit 2, as explained under Sub-section 3.4.6. In terms of the logistics of group-design, propounded by Descombe (1995) and Morgan (1988), this decision made a lot of economic sense.

Table 4.6 shows that teachers were very much in accord with all statements with mean scores ranging from **4.00**, and upwards. Although items (b), (g) and (l) displayed a certain level of indecision and neutrality, with mean-scores lower than **4.00** and above **3.00**, it is safe to argue that these units were reasonably well received. However, the low scores on those items below **4.00** seem to suggest that several of the respondents were not satisfied with the way the units had been introduced and summarized. There were also indications suggesting the two unit tests not adequately covering their respective content areas in the course outline.

***Unit 3***

The pattern of responses on this unit was more or less like what came out of units 1 and 2 combined. Again, most of the unit was reasonably well received, except for three items; (b), (g) and (j) which had lower scores than the rest of the items in Table 4.6. Just like on units 1 and 2, teachers were not satisfied with the way the unit had been introduced and summarized. These two aspects still required attention before full implementation of the materials. However, unlike units 1 and 2, this time there was a marked improvement on content coverage in the unit test. A mean score of **4.51** showed that teachers were satisfied with this aspect, as opposed to **3.67** for units 1 and 2. Despite this improvement, there was a new area of concern in Unit 3 where teachers expressed a certain level of dissatisfaction with the mechanism for 'self-assessment' as represented by Item (j). The exercise could have been better directed. This issue was taken seriously and the necessary improvements were made before implementation of the materials.



***Unit 4***

This unit was very well received since teachers appeared very much in agreement with all the statements as reflected in Table 4.6. With the highest mean score at **4.56** and the lowest at **4.21**, this was a very positive picture. This was a unit simply awaiting implementation before further evaluation at summative level.

***Unit 5***

Table 4.6 shows that while respondents were very satisfied with most of the items, they were not so satisfied with items (g) and (k), to do with the 'Unit Summary' and 'Reflections'. These two items deserved a revisit for the sake of improving the unit before implementation of the materials, particularly Item (k). From the spread of responses on this item, one could see wider variations regarding the views of teachers as reflected by the standard deviation, appearing to be one of the highest among the lot, relative to the mean.

***Unit 6***

Table 4.6 shows that although much of this unit was very well received, the scores on items (h) and (j) suggested the need for improvement on ‘Practice Activities’ and ‘Self-Assessment’. While both mean scores were just above **3.00**, implying wide spread indecision, an examination of responses in individual questionnaires reflected a lot of dissatisfaction where, in several places, respondents indicated that they ‘strongly disagreed’ with the given statements. In both cases, the level of variations suggested by the spread of responses, implied by the standard deviations reflected a lot of internal controversies among respondents. To an extent respondents did not seem to have a consensus in their views on these two items, hence the need for further attention before implementation.



***Unit* 7**

Just like Unit 4, this is another unit that was very well received. Table 4.6 shows all items, from (a) to (n) well above **4.00**, indicating that the respondents were very much in agreement with the various statements. The spread of responses, reflected by the standard deviations, shows that respondents were generally agreeable in their views on this unit.

**Table 4.6** Opinions on suitability of the specimen program, as reflected by responses on the seven units

**N = 45**

| ITEM | Units 1&2 | | Unit 3 | | Unit 4 | | Unit 5 | | Unit 6 | | Unit 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD | M | S/D | M | SD | M | SD |
| **(a)** Topic in this unit is relevant to D&T | 4.7 | 0.7 | 4.5 | 0.8 | 4.6 | 0.7 | 4.5 | 0.7 | 4.4 | 0.7 | 4.5 | 0.7 |
| **(b)** This unit is very well introduced | 3.2 | 0.7 | 3.7 | 0.8 | 4.2 | 0.7 | 4.2 | 0.8 | 4.3 | 0.6 | 4.3 | 0.8 |
| **(c)** Unit well structured & easy to follow | 4.4 | 0.7 | 4.3 | 0.8 | 4.2 | 0.8 | 4.2 | 0.7 | 4.4 | 0.7 | 4.3 | 0.8 |
| **(d)** Unit objectives are very well stated | 4.6 | 0.7 | 4.5 | 0.7 | 4.3 | 0.9 | 4.5 | 0.8 | 4.3 | 0.8 | 4.4 | 0.8 |
| **(e)** Objectives adequately accommodated | 4.3 | 0.8 | 4.3 | 0.8 | 4.5 | 0.7 | 4.4 | 0.8 | 4.2 | 0.7 | 4.3 | 0.7 |
| **(f)** Content in unit relevant and appropriate | 4.5 | 0.6 | 4.5 | 0.6 | 4.4 | 0.5 | 4.4 | 0.5 | 4.3 | 0.7 | 4.3 | 0.7 |
| **(g)** Unit adequately summarized | 3.6 | 0.7 | 3.4 | 0.6 | 4.3 | 0.8 | 3.6 | 0.8 | 4.2 | 0.7 | 4.3 | 0.7 |
| **(h)** Practice activities relevant and useful | 4.7 | 0.6 | 4.6 | 0.7 | 4.4 | 0.7 | 4.5 | 0.6 | 3.5 | 0.9 | 4.5 | 0.6 |
| **(i)** Group activities relevant and useful | 4.7 | 0.6 | 4.5 | 0.7 | 4.5 | 0.7 | 4.5 | 0.6 | 4.3 | 0.9 | 4.4 | 0.8 |
| **(j)** My self-assessment was well directed | 4.3 | 0.8 | 3.6 | 0.8 | 4.3 | 0.8 | 4.3 | 0.8 | 3.5 | 0.9 | 4.4 | 0.6 |
| **(k)** 'Reflection' consolidating understanding | 4.3 | 0.8 | 4.3 | 0.8 | 4.2 | 0.7 | 3.5 | 0.9 | 4.2 | 0.8 | 4.3 | 0.7 |
| **(l)** Unit test adequately covered unit content | 3.7 | 0.7 | 4.5 | 0.7 | 4.5 | 0.7 | 4.6 | 0.7 | 4.5 | 0.7 | 4.3 | 0.7 |
| **(m)** Items in unit test clear & easy to follow | 4.4 | 0.8 | 4.4 | 0.8 | 4.4 | 0.7 | 4.2 | 0.8 | 4.2 | 0.9 | 4.2 | 0.7 |
| **(n)** Unit test useful for revision purposes | 4.7 | 0.6 | 4.7 | 0.6 | 4.5 | 0.6 | 4.6 | 0.5 | 4.4 | 0.7 | 4.5 | 0.7 |



**Key:** M – Mean    SD – Standard Deviation

### *4.2.3 Summative evaluation of the instructional resource package*

All the findings here were based on the responses of the 40 serving teachers belonging to Intake 2. They were responding to the Summative Evaluation Questionnaire (Questionnaire 'D'), designed for the evaluation of the whole course or programme at the core of this study. Just like for the Formative Evaluation Questionnaire (Questionnaire 'C'), whose findings are presented in Table 4.6, the statements in Table 4.7 have been highly compressed for the sake of space. Details of this instrument are shown in appendix 5 and Figure 3.7. According to the instructional design model in Figure 2.2, all investigations at this level were made in line with the last stage, to do with 'Implementation and Summative Evaluation'.

**Suitability of the whole instructional program**

The pattern of responses in Table 4.7 shows a very positive image indicating the whole package of instructional materials being widely received in the end. Responses during the evaluation of individual units (formative evaluation) were a very useful contribution towards the improvement of the whole course.

**Table 4.7** Opinions on suitability of the whole specimen program package

**N = 39**

| Item | M | SD | Item | M | SD |
|---|---|---|---|---|---|
| **(a)** Module relevant for D&T at 'A' Level | 4.4 | 0.8 | **(i)** Sequence of units very easy to follow | 4.6 | 0.7 |
| **(b)** 60 hours adequate for this course | 3.6 | 1.2 | **(j)** Course useful for teaching D&T at 'A' Level | 4.7 | 0.5 |
| **(c)** Overall course aims, clear and easy to follow | 4.6 | 0.6 | **(k)** Units in module have been well introduced | 4.5 | 0.6 |
| **(d)** Overall objectives clear and easy to follow | 4.5 | 0.6 | **(l)** Units in module adequately summarized | 4.5 | 0.7 |
| **(e)** Overall aims well accommodated in content | 4.3 | 0.7 | **(m)** Practice & group activities relevant & useful | 4.4 | 0.9 |
| **(f)** Overall objectives well covered in content | 4.3 | 0.9 | **(n)** Unit tests useful for revision purposes | 4.7 | 0.7 |
| **(g)** Course outline has been easy to follow | 4.7 | 0.5 | **(o)** Overall module test covered whole course | 4.7 | 0.5 |
| **(h)** Whole module well structured | 4.6 | 0.7 | | | |



**Key:** M – Mean score SD – Standard Deviation **COUNT: 39**

However, despite all the positive responses on nearly all the items, Item (b) gave a slightly different picture, when teachers showed that they were not satisfied with the issue of ‘timing’ where they had been allocated 60 hours for the whole course. Under any other comments, most teachers suggested more than 60 hours, with the majority (28 out of 39) proposing 120 hours. Other suggested time allocations were 75, 80 and 100 hours.

One could not ignore the high level of internal variations and movements in the views of teachers on this item as suggested by the spread of responses reflected by such a high standard deviation. This was the highest in the whole table, indicating lack of consensus among the responses.

## 4.3 MAIN RESULTS AND FINDINGS (Going by the secondary research questions)

Following sections 4.1 and 4.2 which had to do with the preparatory investigations leading to the production of the instructional materials and then linking them to their application, the focus is now on this section (4.3) where results and findings are presented in line with the three secondary research questions addressed in this study. According to the methodological framework in Figure 3.1, this section is now specifically founded on the following three of the stages in Ally's (1997) instructional design model: Learner analysis, Content identification and Implementation and summative evaluation. Having results and findings at this level, falling under the three secondary research questions also meant having them (results and findings) rooted in the following primary research question:

'What effect would a specially designed, developed and implemented Material Science (MS) course have on serving teachers in terms of their perceptions and knowledge/understanding regarding content in MS and instructional practice in D&T?'



### *4.3.1 Perceptions of teachers on design and technology as an approach*

Results and findings under this item were in answer to the first secondary research question, going as follows: 'What perceptions of specific aspects of Design and Technology as an approach, do teachers hold?'

The perceptions of teachers on this issue were drawn from their responses to the15 items in Component (B) of the Pre & Post Test Questionnaire (Questionnaire 'A2') before and after both, MS and MSP. It was necessary to establish a clear sense of comparison in order to illustrate the difference between and among responses from the three runs of the questionnaire. Table 4.8 gives a profile of these responses.

Initially, teachers exhibited perceptions that were generally opposed to D&T as an approach, particularly from a Material Science (MS) point of view as represented by the

15 statements in Table 4.8. However, after the MS course, there was a marked difference resulting in more positive perceptions. The picture was even brighter after MSP. In essence, the design of the 15 statements in Table 4.8 was such that, there were those on which low mean scores were the ideal and others on which high scores were ideal if teachers had the right or correct orientation towards the philosophy of D&T. As it turned out, the opposite occurred in most of the cases at pre-test (Pre-MS) level, only to change at the post-test levels.

**Table 4.8** Comparisons among Pre-MS, Post-MS-and Post-MSP scores on the perceptions of teachers on selected items relating to the teaching and learning of MS within the context of D&T

**N = 40** (Pre-MS & Post-MS) **39** (as at Post-MSP)

| **TESTING LEVEL ►** | **Pre-MS** | | **Post-MS** | | **Post-MSP** | |
|---|---|---|---|---|---|---|
| **STATEMENTS ▼** | **M** | **SD** | **M** | **SD** | **M** | **SD** |
| 1. When teaching and learning Material Science, to get focused, there should be no interference from other areas through the so-called subject integration. | 4.30 | 0.72 | 1.38 | 0.67 | 1.31 | 0.47 |
| 2. Since Material Science is closely linked to Machine-Shop Practice, there is no relationship with Physics and Chemistry; subjects whose practical activities are confined to the laboratory. | 3.75 | 0.81 | 1.30 | 0.46 | 1.28 | 0.46 |
| 3. Given so much to cover in Material Science and in view of the shortage of time, the lecture method is the best way to teach it. | 3.90 | 0.71 | 2.10 | 1.1 | 1.67 | 0.48 |
| 4. The problem with group activities in the teaching and learning of Material Science is that learners end up copying each other's work, thereby resulting in very little individual effort. | 4.00 | 0.68 | 1.78 | 0.58 | 1.46 | 0.51 |
| 5. Having Woodwork and Metalwork under the same roof does not allow for depth of learning in each of these disciplines. | 3.98 | 0.8 | 2.13 | 1.18 | 1.67 | 0.48 |
| 6. Material Science is a very difficult and serious subject where the teacher should be in charge of events during the teaching and learning process if there is to be any progress. | 4.00 | 0.6 | 1.93 | 0.98 | 1.69 | 0.47 |
| 7. For reliable assessment of pupils' work in Design and Technology the teacher should always be objective and should not allow for pupil self-assessment. | 4.00 | 0.72 | 1.99 | 0.72 | 1.72 | 0.46 |
| 8. Allowing for pupils' self-assessment usually results in unnecessary disagreements between the teacher and his/her pupils. | 3.80 | 0.79 | 1.95 | 0.88 | 1.67 | 0.48 |
| 9. There is a lot of Material Science implied within traditional subjects like Woodwork and Metalwork. | 2.10 | 1.1 | 4.18 | 1.01 | 4.31 | 0.69 |
| 10. The problem of engaging pupils in brainstorming over design issues is that order is disrupted resulting in chaotic classrooms. | 3.73 | 0.82 | 1.55 | 0.6 | 1.49 | 0.51 |
| 11. Working on mock-ups is as challenging as working on actual artifacts in terms of problem solving in Design and Technology. | 1.85 | 1.0 | 4.15 | 0.83 | 4.18 | 0.82 |
| 12. Material Science is not suitable for teaching and learning at levels lower than 'A' Level. It is too difficult and would confuse pupils. | 3.73 | 0.64 | 1.73 | 0.78 | 1.59 | 0.50 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13. For one who specializes in wood or metal, learning about other materials is a sheer waste of time and resources since s/he rarely uses other materials. | 3.55 | 0.78 | 1.33 | 0.53 | 1.28 | 0.46 |
| 14. It is possible to describe the properties of materials effectively through common sense. | 3.55 | 0.68 | 1.80 | 0.79 | 1.62 | 0.49 |
| 15. Having Design and Technology at 'A' Level instead of Woodwork and Metalwork is an unfortunate development since learners would not have the opportunity to advance themselves in those two important subject areas. | 3.75 | 0.78 | 2.00 | 0.91 | 1.92 | 0.51 |

**Key:** M - Mean; SD - Standard Deviation

One major issue that evolved into another question spinning off as an off-shoot of the official secondary research question was; '--- perceptions held by teachers at what exact point?' The study captured the perceptions of teachers at the three identified levels; pre-test (Pre-MS), Post-MS and Post-MSP. What is important at this stage is to clarify the patterns of perceptual changes and comparisons immerging from the specified levels. The initial perceptions of teachers were totally different from what they ended up with on nearly all the cases/statements.

A comparison of the perceptions of teachers across the three runs of Questionnaire 'A2', as displayed in Table 4.8 shows a marked difference, especially between the pre-test (Pre-MS) and the Post-MS scores. A more or less similar situation goes for comparison between the Pre-MS scores and those after MSP, considering the equally wide gap across the board.



Generally, from the pattern of scores in Table 4.8 starting from the variations illustrated in Tables 3.1 (a) and (b), there was a marked difference between the pre-test and post-test experiences. Indications were that the MS course made a great difference in the development of positive perceptions in teachers towards D&T as an approach. In fact, this shift from negative to positive perceptions was ample evidence of a lot of learning having occurred. After the course, teachers saw issues differently in relation to the teaching and learning of MS within the context of D&T.

### *4.3.2 Knowledge/understanding of concepts in MS*

Results and findings under this sub-section were in answer to the following secondary research question (second): 'What knowledge/understanding of specific concepts in

Material Science do teachers hold in relation to the teaching and learning of Design and Technology?' Knowledge/understanding of these concepts was determined through responses to components (C) and (D) of the Pre & Post Test Questionnaire (Questionnaire 'A2'), in addition to performance during the final examination. Appendices 3 and 29 show the questionnaire and examination paper. These two components [(C) and (D)] were concerned with 'knowledge of materials' and 'level of confidence on given items', as explained in Chapter 3. While Part (C) was the main mechanism designed to determine the level of understanding at the three pre-determined stages (Pre-MS, Post-MS and Post-MSP), responses to Part (D) and performance in the examination were there to cross-check or corroborate the results and findings from Part (C).

Having started with very low understanding on the 30 selected items in Part (C) and very low confidence on the various topics and sub-topics in Part (D) of the questionnaire at pre-test level, teachers later exhibited much higher levels of understanding and confidence at Post-MS and Post-MSP levels. They also performed reasonably well during the unit-tests and final examination in MS, where an overall average mark of 65%, inclusive of coursework, was earned from the 40 entries, representing the serving teachers belonging to Intake 2 (2003–2004). In this case, the highest mark was 80% while the lowest was 53%.



Similar to the trend on perceptions, the gap between indications from the Post-MS and Post-MSP runs of Questionnaire 'A2', on components (C) and (D) was not as wide as that between pre-test (Pre-MS) and either of them. Tables 4.8 (a) and (b) clearly show this trend. In both cases, the bottom line remained the same; the fact that although teachers started from a very low ebb regarding knowledge and confidence on specific items, the MS course contributed immensely towards the marked improvement witnessed between the pre-test and the latter tests.

**Knowledge/understanding of materials**

Judging by the outcome of the pre-test (Pre-MS) responses [4.9 (a) and (b)], teachers did not initially appear to have a strong enough or an adequate scientific background, in relation to the nature of materials. The demographic data for the 40 teachers confirmed this shortfall in terms of scientific knowledge/understanding. Asked to indicate what subject combinations they had had during their initial teacher training; only three indicated having combined a technical subject and a relevant science related area like Physics or Chemistry. Of these, one indicated having combined Metalwork and Science while the other two had combined Woodwork and Science. The rest indicated combinations comprising only technical subjects; in this case, Woodwork and Metalwork.

Indeed, after the MS course there was a marked difference in a positive sense, resulting in teachers demonstrating a generally much higher level of scientific knowledge and understanding as shown in tables 4.9 (a) and (b). From the pattern of responses in these tables, one can see the impact that the MS course had had on the capacity of these teachers, in terms of scientific knowledge/understanding of materials. Teachers ended up more knowledgeable than when they came into the program. And as already indicated, this was also confirmed by the final assessment in MS. Their knowledge of MS was also useful during MSP where there was adequate evidence of teachers being better informed in the application of materials as they got involved in hands-on problem-solving activities.



**Table 4.9 (a)** A comparison between Pre-MS, Post-MS-and Post-MSP scores on the teachers' knowledge of materials focusing on items 1 to 15 of the 30 from Section (C) of Questionnaire 'A2'

**N = 40** (Pre-MS & Post-MS) **N = 39** (as at Post-MSP)

| TESTING LEVEL ► | Pre-MS | | Post-MS | | Post-MSP | |
|---|---|---|---|---|---|---|
| STATEMENTS ▼ | M | SD | M | SD | M | SD |
| 1. Different materials have the same type of atom. Only diff. being arrangement of atoms in various materials. | 4.2 | 0.6 | 1.4 | 0.5 | 1.33 | 0.47 |
| 2. Electrons differ, depending on the types of materials. | 4.1 | 0.8 | 1.4 | 0.5 | 1.49 | 0.51 |
| 3. In hot weather, wooden structures expand due to heat absorption. | 2.7 | 1.0 | 1.4 | 0.5 | 1.46 | 0.51 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4. All known matter on earth is represented in the periodic table. | 2.2 | 1.0 | 4.6 | 0.7 | 4.72 | 0.60 |
| 5. The melting point of any metal in Sweden differs from that in Zimbabwe due to differences in weather. | 3.3 | 1.8 | 1.3 | 0.5 | 1.33 | 0.48 |
| 6. Heated metals expand due to the increase in atoms per unit cell absorbing more atoms from the heat. | 3.5 | 1.0 | 1.4 | 0.5 | 1.36 | 0.49 |
| 7. The main disadvantage of all plastics is that they soften when heated. | 3.7 | 1.1 | 1.4 | 0.5 | 1.36 | 0.49 |
| 8. The effects of moisture absorption and loss are equal in all the dimensions in a piece of wood. | 3.5 | 0.9 | 1.4 | 0.5 | 1.33 | 0.48 |
| 9. On cooling, metals shrink due to the loss of atoms. | 3.6 | 0.9 | 1.4 | 0.5 | 1.41 | 0.50 |
| 10. Rate of expansion of in iron bar differs, depending on where you are; hot or cold regions of the world. | 3.1 | 1.6 | 1.6 | 0.5 | 1.46 | 0.51 |
| 11.Steel is used to reinforce concrete structures because it elongates at the same rate with concrete. | 4.2 | 1.2 | 1.5 | 0.5 | 1.38 | 0.49 |
| 12. Just like in copper, cold working raises the hardness level of lead. | 4.1 | 1.0 | 1.4 | 0.5 | 1.33 | 0.48 |
| 13. In hot weather, asphalt becomes very hard due to the effects of heat. | 3.5 | 1.0 | 1.4 | 0.5 | 1.28 | 0.46 |
| 14. A piece of wood has the same strength qualities all round. | 2.5 | 1.5 | 1.4 | 0.5 | 1.36 | 0.49 |
| 15. Zinc and copper do not corrode at all in the atmosphere. | 3.7 | 1.0 | 1.5 | 0.6 | 1.36 | 0.49 |

**Key:** SD – Standard Deviation



An important observation at this point is that, although the general trend on the issue of knowledge/understanding was a situation where teachers started off displaying relatively low levels across the board, there were however a few encouraging cases where teachers showed reasonable levels of knowledge/understanding right from the start. Typical examples were items 17, 18 and 26 in Table 4.9 (b).

**Table 4.9 (b)**: A comparison between pre-MS, post-MS-and post-MSP scores on the teachers' knowledge of materials focusing on item 16 to 30 of the 30 from Section (C) of Questionnaire 'A2'

**N = 40** (Pre-MS & Post-MS) **N = 39** (as at Post-MSP)

| **TESTING LEVEL ►** | **Pre-MS** | | **Post-MS** | | **Post-MSP** | |
|---|---|---|---|---|---|---|
| **STATEMENTS ▼** | **M** | **SD** | **M** | **SD** | **M** | **SD** |
| 16. In metals, the rate of expansion differs, depending on the orientation in terms of dimensions (e.g. length and width). | 3.9 | 1.0 | 1.6 | 0.6 | 1.64 | 0.54 |
| 17. The higher the temperature in semi-conductors, the higher the electrical conductivity. | 3.1 | 1.3 | 4.5 | 0.6 | 4.59 | 0.59 |
| 18. The diameter of an atom depends on the number of electrons around the nucleus. | 3.0 | 1.3 | 4.5 | 0.6 | 4.38 | 0.63 |
| 19. The weight of an atom is mainly determined by the nucleus. | 2.7 | 1.3 | 4.5 | 0.5 | 4.62 | 0.49 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 20. The volume of an object has a direct link to its (object) density. | 4.1 | 0.9 | 1.5 | 0.5 | 1.41 | 0.50 |
| 21. There is a strong correlation between hardness, tensile strength & cold work when dealing with metals. | 1.9 | 0.8 | 4.4 | 0.5 | 4.51 | 0.51 |
| 22. Plastics are totally different from metals and methods of processing them also differ. There are no similarities at all. | 3.5 | 1.1 | 1.5 | 0.5 | 1.44 | 0.50 |
| 23. Plastic strain results in temporary deformation in metals. | 3.9 | 1.3 | 1.5 | 0.5 | 1.41 | 0.50 |
| 24. Solid solution copper is one grade of pure copper. | 3.5 | 0.8 | 1.5 | 0.6 | 1.36 | 0.50 |
| 25. Because of its density, magnesium is a lot heavier than aluminum. | 3.6 | 1.0 | 1.5 | 0.5 | 1.36 | 0.49 |
| 26. Recent explorations have revealed massive deposits of magnesium in the sea. | 3.0 | 1.0 | 4.4 | 0.7 | 4.44 | 0.68 |
| 27. There are some softwoods that are much harder than some hardwoods. | 2.6 | 1.1 | 4.7 | 0.5 | 4.72 | 0.46 |
| 28. Diamond is one of the hardest metals used in tool making. | 4.1 | 1.3 | 1.4 | 0.5 | 1.26 | 0.44 |
| 29. The electrical conductivity of copper increases with more solid solution. | 4.2 | 0.8 | 1.5 | 0.6 | 1.44 | 0.50 |
| 30. Given its high strength, carbon steel makes the most durable & reliable bushes for starter motors. | 4.1 | 0.8 | 1.5 | 0.5 | 1.38 | 0.49 |

**Key:** SD – Standard Deviation



### Level of confidence on teaching selected elements of MS at 'A' Level

Results and findings under this topic were specifically obtained from responses to Part (D) of Questionnaire 'A2', as already indicated at the beginning of this sub-section (4.3.2). All the relevant items were in this case, directly drawn from the course outline of the instructional materials, going according to the same topics as shown in appendices 3 and 6.

Across the board, the general indication was that the pre-test of Questionnaire 'A2' on this issue, revealed a great lack of confidence in teachers, regarding the teaching of MS at 'A' Level. This showed that teachers needed a lot of help on nearly all the areas if they were to assist pupils/students effectively in their teaching. However, after the MS course, there was a general gain in confidence and the trend was maintained and reinforced after MSP. The comparison between the Pre-MS and the post-test scores in Tables 4.10 show that teachers gained a lot of knowledge/understanding from the course in MS and from the way it was related to MSP, in terms of integration. In fact, the application of MS within the context of MSP appears to have made a difference in raising the confidence of teachers, regarding teaching the various topics at 'A' Level.

Considering the situation in Table 4.10, on all the topics from Item 1 to Item 7 and the related aspects, going from Pre-MS up to Post-MSP, there appears to have been a high level of internal consensus reading from the magnitude of the respective standard deviations, relative to the mean scores. The only exception was Item 2 (d) under Metallic Structures where a Post-MS Standard deviation of **1.00** appeared too high relative to a mean score of **3.90**. This wide spread of responses around the mean was an indication of lack of consensus among respondents on the issue of ‘phase transformations in metals’. There appears to have been a few mixed feelings as demonstrated by such a wide spread of responses, away from the mean.

Other notable observations included situations where the following trends were of particular interest:

(a) Standard deviations generally tended to progressively decline across the board, from Pre-MS to Post-MSP and on all the items, the last was by far the smallest. On the one hand, this was an indication of more variations in responses at the first two levels, especially at Pre-MS Level. On the other hand, showing consensus among respondents, the smallest standard deviations featuring at Post-MSP level seemed to be an indication of respondents being most resolute in their responses and views. The latter situation was most likely a function of more and decisive understanding of the issues at hand, which appeared to go with more confidence. The more understandings teachers gained, the more confident they seemed to become on all items.



(b) The gap between the pre-and post-test scores remained consistently wide throughout and in the end this ceased to be news. This was typical of all the topics and their respective components. The whole pattern of scores seemed to indicate a drastic jump from a general lack of knowledge/understanding of the issues in question, to a situation where teachers had gained adequate knowledge and understanding from MS to exhibit this level of difference.

(c) The gap between the Post-MS scores and those from the Post-MSP was relatively small. Given the impact of the MS course on the understandings of teachers, this was not surprising. The turning point appears to have been the shift from responses at Pre-MS level to those after the MS course. However, despite being small, the gap between the two post-tests was significant and in most cases it was an indication of the value added by the application of MS under MSP. This clearly demonstrated the impact of applying MS in problem solving under MSP. Such value was vivid in nearly all the cases where the Post-MSP score was greater than the Post-MS score, the only exception being Item 1 where the Post-MS score was greater that the Post-MSP. In this case, there was a drop of 0.14, from a Post-MS Mean of 4.78 to a Post-MSP mean of 4.64. However, after a close examination of raw data from the original responses in comparison tables, there was not much of a difference. The final picture remained that of teachers expressing enough confidence in teaching the topic at 'A' Level.

Apart from the general observations so far highlighted, there were also others that were specific to particular topics in Table 4.10. Therefore, it is now perhaps time to identify the specific points at which the findings here related to those in Part (C) of the Pre- & Post Test Questionnaire (Questionnaire 'A2'), on a case by case basis.



***Focus on engineering materials in general***

In terms of links with the issue of 'Understanding in Part (C) of Questionnaire 'A2', responses on this topic were reflective of the understanding exhibited on items 1, 2, 4, 13 and 28; concerned with the atomic structure of materials, the electronic configuration of materials, the nature of asphalt as an engineering material and the classification of materials in the periodic table. Even then, although teachers began with very low levels of understanding, after the MS course, they became more knowledgeable and ended up with higher levels of understanding on these issues and their related concepts. This also explains the relatively high levels of confidence generally and progressively exhibited by teachers on this topic.

**Table 4.10** Confidence on teaching various topics and/or sub-topics under Material Science (topics 1 to 4)

**N = 40** (Pre-MS & Post-MS) **39** (as at Post-MSP)

| **TESTING LEVEL ►** | **PRE-MS** | | **POST-MS** | | **POST-MSP** | |
|---|---|---|---|---|---|---|
| **ELEMENTS ▼** | **Mean** | **SD** | **Mean** | **SD** | **Mean** | **SD** |
| **1. ENGINEERING MATERIALS IN GENERAL** | 2.40 | 0.60 | 4.78 | 0.50 | 4.64 | 0.50 |
| (a) Three main families of engineering materials | 2.23 | 0.77 | 4.58 | 0.59 | 4.62 | 0.54 |
| (b) Bonding forces in different materials | 1.53 | 0.60 | 4.48 | 0.68 | 4.64 | 0.49 |
| **2. METALLIC STRUCTURES** | 1.90 | 0.78 | 4.35 | 0.77 | 4.51 | 0.51 |
| (a) Metal atoms | 1.75 | 0.78 | 4.43 | 0.78 | 4.51 | 0.50 |
| (b) The periodic table | 1.60 | 0.55 | 4.50 | 0.78 | 4.67 | 0.48 |
| (c) The unit cell | 1.55 | 0.55 | 4.33 | 0.80 | 4.54 | 0.51 |
| (d) Phase transformations in metals | 1.53 | 0.70 | 3.90 | 1.00 | 4.44 | 0.50 |
| (e) Effects of other elements on the structure of pure metals | 1.58 | 0.64 | 4.20 | 0.80 | 4.41 | 0.64 |
| **3. EFFECTS OF STRESS AND TEMPERATURE ON METALS** | 1.58 | 0.70 | 4.10 | 0.80 | 4.46 | 0.51 |
| (a) Plastic strain, permanent deformation and slip | 1.65 | 0.70 | 4.15 | 0.80 | 4.51 | 0.51 |
| (b) Cold work or work hardening | 1.85 | 0.74 | 4.48 | 0.78 | 4.59 | 0.64 |
| (c) Effects of elevated temperatures on work hardened structures | 1.63 | 0.60 | 4.33 | 0.73 | 4.46 | 0.51 |
| (d) Selection of annealing temperatures | 1.78 | 0.77 | 4.05 | 0.85 | 4.41 | 0.50 |
| (e) Effects of grain size on properties | 1.55 | 0.60 | 4.23 | 0.63 | 4.44 | 0.50 |
| **4. ENGINEERING ALLOYS (Non-ferrous)** | 2.15 | 0.80 | 4.63 | 0.54 | 4.67 | 0.48 |
| (a) Aluminum alloys | 2.20 | 0.65 | 4.70 | 0.56 | 4.77 | 0.43 |
| (b) Magnesium alloys | 1.68 | 0.66 | 4.65 | 0.58 | 4.74 | 0.44 |
| (c) Copper alloys | 2.15 | 0.70 | 4.80 | 0.46 | 4.82 | 0.39 |
| (d) Nickel alloys | 1.65 | 0.70 | 4.63 | 0.63 | 4.72 | 0.46 |
| (e) Titanium alloys | 1.45 | 0.60 | 4.58 | 0.75 | 4.69 | 0.47 |
| (f) Zinc alloys | 2.00 | 0.75 | 4.65 | 0.58 | 4.74 | 0.44 |



**Key**: SD – Standard Deviation

*Focus on metallic structures*

The general trend of the findings on this topic appeared to be closely related to the outcome on particular components in Part (C) of the Pre-& Post-Test Questionnaire (Questionnaire ‘A2’). Specifically these included items; 1, 2, 4, 6, 9, 10, and 19. Collectively, these items had to do with issues relating to; atomic/electronic theory, the periodic table and the effect of heat on metallic structures. The general observation is, similar to the trend where teachers started with very low understandings of these issues before MS and improved after the course, they also went through a similar pattern in gaining confidence on these issues.

**Table 4.10** (Continued) Confidence on teaching various topics and/or sub-topics under Material Science (topics 1 to 4)

**N = 40** (Pre-MS & Post-MS) **39** (as at Post-MSP)

| **TESTING LEVEL ►** | **PRE** | | **POST-MS** | | **POST-MSP** | |
|---|---|---|---|---|---|---|
| **ELEMENTS ▼** | **Mean** | **SD** | **Mean** | **SD** | **Mean** | **SD** |
| **5. STEEL, CAST IRON, DUCTILE IRON & MALLEABLE IRON** | 1.98 | 0.70 | 4.15 | 0.58 | 4.28 | 0.46 |
| (a) The iron-iron carbide diagram and its phases | 1.38 | 0.54 | 3.88 | 0.82 | 4.31 | 0.47 |
| (b) Plain carbon and low alloy steel (equilibrium structures) | 1.65 | 0.74 | 4.05 | 0.78 | 4.41 | 0.50 |
| (c) Hypoeutectoid and hypereutectoid steels | 1.40 | 0.55 | 4.00 | 0.85 | 4.31 | 0.47 |
| (d) Hardenability of steel | 1.63 | 0.74 | 4.13 | 0.79 | 4.36 | 0.49 |
| (e) Stainless steels | 1.65 | 0.70 | 4.23 | 0.73 | 4.46 | 0.51 |
| (f) White iron, gray iron, ductile iron and malleable iron | 1.88 | 0.80 | 4.10 | 0.87 | 4.44 | 0.55 |
| **6. COMPOSITE MATERIALS; Including Concrete and Wood** | 1.95 | 0.60 | 4.38 | 0.54 | 4.54 | 0.51 |
| (a) Synthetic composites | 1.75 | 0.67 | 4.35 | 0.80 | 4.54 | 0.60 |
| (b) Concrete and its components | 1.88 | 0.69 | 4.50 | 0.64 | 4.64 | 049 |
| (c) Properties of concrete | 1.98 | 0.77 | 4.60 | 0.63 | 4.74 | 0.44 |
| (d) Special concretes | 1.70 | 0.65 | 4.58 | 0.59 | 4.72 | 0.46 |
| (e) Wood as an engineering material | 2.15 | 0.80 | 4.63 | 0.70 | 4.77 | 0.43 |
| (f) Wood macrostructure | 2.13 | 0.72 | 4.58 | 0.71 | 4.74 | 0.44 |
| (g) Wood microstructure | 1.65 | 0.66 | 4.60 | 0.78 | 4.54 | 0.79 |

| | | | | | | |
|---|---|---|---|---|---|---|
| (h) Properties of wood | 2.08 | 0.76 | 4.68 | 0.62 | 4.72 | 0.56 |
| (i) Asphalt as an engineering material | 1.60 | 0.55 | 4.63 | 0.49 | 4.74 | 0.44 |
| **7. PLASTICS** | 1.90 | 0.78 | 4.50 | 0.60 | 4.59 | 0.55 |
| (a) The concept of polymerization | 1.48 | 0.60 | 4.43 | 068 | 4.54 | 0.51 |
| (b) Polymerization types | 1.48 | 0.51 | 4.38 | 0.63 | 4.46 | 0.60 |
| (c) Processing of plastics | 2.03 | 0.77 | 4.58 | 0.64 | 4.64 | 0.58 |

**Key:** SD – Standard Deviation

***Focus on the effects of stress and temperature on metals***

Drawing parallels between aspects under this topic and those in Part (C) of Questionnaire 'A2', one could see links with items 6, 9, 10, 12, 16, 21 and 23, collectively to do with the following issues in relation to metals; the effect of heat, cold working and plastic strain. From the way teachers responded to these items, it appears their newly acquired knowledge of materials had an influence on the progressive growth in their confidence.

***Focus on engineering alloys (non-ferrous)***



Compared to all the areas so far covered, this was the first situation where despite maintaining the relatively wide gap between the Pre-MS scores and the last two scores (Post-MS and Post-MSP), the one (gap) between the last two was the narrowest and most highly negligible, with some being almost equal. One could not help suspecting this situation being linked to Pre-MS scores that were also relatively high, suggesting relatively high confidence from the start. The initial levels of confidence on this topic were only comparable to those under Item 1 in Table 4.9, to do with 'Engineering Materials in General'.

In terms of the relationship between various findings under this topic and those under Part (C) as displayed in tables 4.9 (a) and 4.9 (b), links were identified with items 12, 15, 24, 25, 26, 29 and 30, generally concerned with issues relating to; non-ferrous alloys, corrosion in metals, corrosion resistance of non-ferrous metals, solid solution mechanisms, processing and production of materials.

*Focus on steel, cast iron, ductile iron and malleable iron*

From the way teachers responded, as shown in Table 4.10, there were similarities with findings made under items 5, 6, 9 and 30 from Part (C) of Questionnaire 'A2', as reflected in tables 4.9 (a) and (b). Although teachers started with low understanding, after MS they demonstrated a reasonably high level of understanding on various concepts and issues relating the following phenomena: heat transfer in metals, thermal conductivity, the iron–iron carbide phase diagram, and appropriate application of materials. And, coming to Part (D) of the questionnaire, one could then understand the high level of confidence eventually displayed by the teachers, regarding teaching at 'A' Level.

*Focus on composite materials*

Results and findings on this topic were closely related to those on items 3, 8, 11, 13, 14 and 27 displayed in tables 4.18 (a) and (b) as taken from Part (C) of Questionnaire 'A2'. These six items broadly dealt with: the physics and chemistry of materials, the behaviour of materials under different conditions, the need to strengthen materials in various applications, and the classification of materials. Despite having started with very low levels of confidence teachers later became very confident after the MS course.

*Focus on Plastics*

On this topic and its related aspects, the general shift from low to high confidence could be traced back to specific items of relevant areas of knowledge presented in tables 4.8 (a) and (b), where items 7 and 22 appeared particularly interesting. Generally, these items involved knowledge about the chemistry and physics of plastics, processing of plastics, and the relationship between plastics and metals regarding methods of processing. After teachers acquired this kind of knowledge, it was not surprising to see them eventually exhibiting the confidence displayed in Table 4.10, in relation to the teaching of this topic and its related aspects at 'A' Level.

### *4.3.3 Application of MS in solving practical problems*

Results and findings under this item were in answer to the following secondary research question (3rd): 'To what extent are teachers competent to apply the knowledge/understanding gained from the Material Science course in solving practical problems under the Machine Shop Practice course?' This question was viewed in two ways; where teachers were expected to solve practical problems either by handling a practical design problem in a teaching and learning situation during class activities under the Material Science (MS) course or working on artefacts during workshop activities under the Machine Shop Practice (MSP) course. Firstly, teachers could be seen solving practical problems by way of class or group discussions. Secondly, they could be seen manipulating tools/equipment and materials in a workshop environment. In this case, 'practical problems' were considered to be relative, depending on the situation or context at hand. On the one hand, it meant solving real problems in a situation even if they were theoretical in nature. On the other hand, it meant literally solving a practical design problem in the sense of being technical in nature.



The application of MS, in solving practical problems during MSP was demonstrated at various levels as teachers were observed working in workshops during the 60 hours of lectures and 20 hours of the practical examination. Data from interviews also helped to corroborate and confirm this as teachers claimed having found their knowledge of MS applicable during their practical activities. More evidence of teachers applying their theoretical and practical knowledge in problem-solving was also found within their project reports in the design folios for the various artefacts designed and fabricated under MSP.

**Cohort '1' interviews**

From the18 participants here, very important answers helped to prove the point that teachers were applying their knowledge of MS in solving practical problems under MSP. Responding to specific questions, they described and explained how they had found their knowledge of MS applicable in their practical activities under MSP. Appendix 10 shows details of these teachers while Appendix 7 shows the interview guide that was used in this case. Results and findings were according to specific key issues as presented below.

***The relationship between MS and MSP***

Asked to indicate what they considered to be the relationship between MS and MSP, all the teachers acknowledged a definite link between these subjects, and they proceeded to elaborate on how one could apply his/her knowledge of MS to solve practical problems or explain phenomena under MSP. They also gave examples from their personal experiences. The following answers by some of the teachers, taken word for word, could perhaps give a clue of the direct messages from them:

- **Teacher 1** (3): I think MS that we did last semester is very relevant in the D&T that we are doing now, because you find--e-e--, we are now able to--we have a vast knowledge of materials that are available for us as designers and we are now being able to implement them in our designs.
- **Teacher 2** (5): E-e, there is a relationship, because what I learnt in MS, we did types of materials, their application, e-e- the science behind materials. So, I am applying this in my e-e, in my course right now in MSP, because sometimes you have to plan for materials when designing. So when I know, now that I know the characteristics of materials, I can choose relevant materials for particular applications
- **Teacher 3** (6): In MS, we dwelt much on materials that are used in engineering, right. And, in MSP we are now using those different types of materials-- materials that we are learning in Material Science to manufacture small artefacts in our practical projects. Currently, we--we are manufacturing a simple auto-mata toy, a toy that has got different mechanisms. So, we are trying to use as much materials as possible in trying to come up with a toy that has got different links and mechanisms.
- **Teacher 4** (10): Yes, the relationship is there, especially where you have to relate materials to the design. When selecting materials for the prototype, we choose the material on the basis of what we learnt in MS.
- **Teacher 5** (13): Ya-a, ---. There is a relationship. We--we learnt about characteristics of—of materials and as a result, we're applying those characteristics in selecting materials for designing --- in our designing course.
- **Teacher 6** (15): Y---, yes, th--the--of course there is a lot of relationships between MS and MSP. The MS was actually a kind of basis of what we are now doing in MSP. And the basis we got in MS was really good. Now we have the ability to choose between materials to be used in a given design.



Note: The numbers in brackets are the original ones featuring in the main data base for the 18 interviews in this cohort. The ones in bold are mainly for the sake of order and for the purpose of presentation in this report.

From these statements by the six teachers, given as examples here, the actual voices are a clear testimony of their active application of MS under MSP. Appendix 11 shows more details on accounts from the rest of the teachers, excluding the six presented here, to make a total of 18. Most of the answers also showed that teachers appropriately related these subjects from a practical perspective.

***An indication of teachers having a chance to apply their knowledge of MS under MSP***

When teachers were asked whether or not they were having a chance or chances to apply their knowledge of MS in their learning of MSP, they all confirmed the positive. Phrases like; 'oh yes, yes, --- yes', 'very much so', 'oh yes', 'definitely yes' 'sure', 'definitely', 'yes, so many chances' and 'ha-a, of course' were some of the answers given. These sounded convincing enough to show the sincerity behind. The following statements taken word for word from six teachers also help to give an idea of the responses confirming the actual application of MS in MSP:

- **Teacher 1** (1): Very much, especially in designing! Also, also, E-ee actually like right now, we have got a project that we are making about toys. So, we need to know the composition of the--of the material that makes the body and you know friction, so when you consider all those factors you find that you are actually designing something that is quite appropriate for the given situation.
- **Teacher 2** (3): Oh, yes definitely. Yes--because you find e-e-the--, like the projects that we have done so far, right now we are focusing on a toy project for small children. So, you find out that, like the knowledge we got in plastics, that we did last semester, is very beneficial because toys are supposed to be made out of plastics,--now that we know.
- **Teacher 3** (10): Yes. When selecting the materials for the prototype, we choose the material on the basis of what we learnt in Material Science.
- **Teacher 4** (12): Yes, yes, yes. Presently there is, unlike when we started---when we were doing Part 1 of this Design, last year, some of us didn't know anything about some of these materials, especially metals. In MS, we learnt more about metals, concrete, plastics ---applying that knowledge.
- **Teacher 5** (15): Oh--yes, yes--because--like we--, let me give you an example of my research ---I am doing right now. It involves--a-a-number of mechanisms---gears ---choice of materials depends on MS.
- **Teacher 6** (16): Actually--we have--we are having that chance because you find--this toy--it has to--it has to be used by children of--very--very--tender age; that's the 2 years to 7 years and it has to be light. It has to be made from materials, which are not poisonous. The selection of those materials--- requires a lot--, and that's where we are getting the information from the course we did in MS.

From these statements, it appears teachers had ample opportunities to apply their knowledge of MS under MSP. For example, they even went to the extent of giving examples of the various situations under which such opportunities occurred. Appendix 12 shows accounts from the other 12 teachers on this issue.

*Evidence of teachers applying knowledge of Material Science*

The issue of teachers having a chance to apply their knowledge of MS under MSP as explained above was closely related to the evidence required here. Asked to indicate where exactly they could have applied their knowledge of MS, all the teachers had a lot to say about their individual experiences. They had applied such knowledge in several ways and places within MSP and they all proceeded to provide descriptions of what they considered evidence. While the rest of the accounts from teachers on this issue are presented in Appendix 13, below are some outstanding highlights from six teachers. Again, the numbers in brackets are the identities applied in the original data base.

- **Teacher 1**(4): Yes. Right now we are-e-e- we are doing -a- a project on toy-auto-motor (auto-mata) --- for children. You find that, because of the age that you are looking at,--you need to consider that some children can take that toy and start chewing it. So, ---if the material is poisonous, you find it dangerous. If you say, you might want to use glass, that can also break ---, it becomes dangerous-e-saka, (Shona for '*so*') ---we are really implementing the knowledge of MS in our designing activities.
- **Teacher 2** (7): I would say for example--, I'll give an example-- (clearing throat). For example, when -e- I- for bending-- you have got first of all to have knowledge of 'cold working' and annealing. That's one example that I can give.
- **Teacher 3** (9): Yes, yes, yes. Even on the cutting list of materials on the--of the toy project, I actually put the materials which I learnt in my Material Science, of which, it shows that I am actually applying what I learnt from my Material Science course.
- **Teacher 4** (10): The evidence--should be there--it's there. Because basically, what we are doing is--we are designing -e- that mechanized toy, but with the materials we--which we are using for the realization of the model, it's not metal as such, much of the materials. But when we relate the-e-say the material, which we need for the prototype that's when the Materials Science comes in.
- **Teacher 5** (13): Yes, there is--to a great extent--I can say--because you find out that--you--for instance, the question which we are looking at in designing, we were required to design and make a prototype toy. You have to make use of materials such as metal, wood and plastic.
- **Teacher 6** (16): Yes, there is, -e- because currently like we--are-are doing some projects. We are doing the second project--the second project in this semester and we have done another one, which was based on farming equipment focusing on the new farmers just resettled by the government.

Although these statements might arguably not have been adequate evidence as expected here, at least they helped to give a clue of the extent to which teachers were actively applying their knowledge of MS in their learning of MSP. A lot of what they said justified the need to check for more evidence from their personal records in design folios in order to get a full account of the situation.

These statements also gave a vivid picture of how teachers had applied their knowledge of MS under MSP. They were not empty claims based on wishful thinking. Teachers had actually found their knowledge applicable and useful in real problem solving situations. Most of these claims were confirmed during observations of workshop activities where teachers were seen handling equipment and materials in the process of solving specific practical problems. More evidence was also available in design folios, where teachers made informed decisions in the choice of materials for particular applications based on their nature, in terms of physical and chemical properties. Some of the choices they made could hardly have been possible without adequate knowledge of the scientific principles behind materials. For example, there were cases where teachers had to make a distinction between, friction as a problem and friction as a solution to a problem in a given mechanism or situation.

Teachers also elaborated on the problems they encountered in their efforts to apply MS in their learning of MSP. While 11 teachers out 18 reported that they were not experiencing any problems, 7 reported the following:



- Lack of some of the materials on the market. Where a few were available the prices were quite exorbitant and prohibitive.
- Due to lack funding, especially for materials, most of the planned projects remained and ended at mock-up stage without further progress into the real materials, apart from cheap card.
- Some of the projects, especially the toy, were not challenging enough.
- Inadequate time for all the required activities.

The 7 teachers who highlighted these problems seemed to consider them part of the factors that tended to hinder their progress in as far as their application of MS was concerned. For the purpose of this study, that was interesting to note in view of the environment and conditions under which teachers were working. Appendix 14 shows more details on issues relating to the problems highlighted above.

When teachers were asked to describe and explain the ways in which they could see themselves assisting pupils/students in their learning of D&T, in view of what they had learnt in MS and MSP, they indicated that they were going to assist their pupils/students in several ways. However, the follow-up question was, 'In what ways?' All the relevant details are presented in Appendix 15 and only a few outstanding examples have been highlighted below, going as follows:

- **Teacher 1** (5): **YES:** Y-e-s-Yes, yes. I have to, because e-e before I came here I wouldn't--I wouldn't have had the knowledge that I have now. So, I have to tell them, I have to explain thoroughly, the differences between materials and their applications, because in my course at Belvedere, we--we didn't go that deep. We will just talk about materials and maybe at face value without even considering the science behind materials,--the chemistry behind materials. Now that I know it, I think I will have to teach the pupils because they have to know it as well and they can apply that so that we--we--we have designs that are quite e-e- strong and we have articles that are durable and also functional.
- **Teacher 2** (6): **YES:** Definitely, wh-what I have learnt was--was -a- a great eye opener. I think I am going to use --- I am going to use Material Science as much as I can in schools. Now that I know the different applications of different materials, someone will take for granted. So, I would make sure that-in-in my work with the pupils,--I'll try to incorporate most of the things that I have learnt in the subject.
- **Teacher 3** (9): **YES:** Definitely, a -I-actually, it's only a matter of time. Let me say, I will start implementing that because there is no way I can just say, 'pupils go and design without them investigating thoroughly why they should use different types of materials on their projects because these you can not distinguish -e-e-, woodwork or metal because when you design you just select materials which are proper. On a project which is made in Woodwork you can use plastics. There are many materials. You may find metallic parts. We have got stays. We have got handles -e-e- even some parts, shelves, which are made out of glass. We tend to mix a lot of materials. So, there is that need for me to actually equip the pupils to know why they select those materials.
- **Teacher 4** (17)**: YES:** I –like--I am looking forward to a situation whereby, when I go back to my station, I --I will have to use the knowledge gained in Material Science and Machine Shop Practice. I am going to have my junior classes working on 'card' before they proceed on working on wood because I feel, the costs--it's more cost effective really to work with card than actually on wood. I am looking at things like this in Bulawayo for example where I am stationed, a-a -- I am seeing myself now being able to take my students for field trips where they will be able to really see--e--these materials being manufactured. I can take the--to--, I can take them to--to people who,--who are manufacturing dishes--you know they are in the plastic business--and things like that. That's what I would like them to see.

From all these profiles, it is clear that all teachers were willing to assist pupils/students back in their schools. They sounded reasonably confident about this. Given a chance and the necessary support, most of them hoped to succeed in doing that, in view of the knowledge they had acquired. These responses by teachers could be related to their show of confidence as already indicated under Sub-section 4.3.2. Generally, the responses also appeared to confirm the high levels of confidence teachers ended up with after both, MS and MSP courses. However, there were some teachers, who after having said "YES", were quick to then also say, “BUT”. These were voices of doubt and concern that could not be ignored.

***Doubts and problems expressed by teachers***

Further scrutiny of what teachers were saying, showed that they had a few fears, reservations and doubts about fulfilling all their wishes regarding the implementation and teaching of MS and MSP under the auspices of D&T back in their schools. Typical examples of such voices include those from teacher numbers 10, 13 and 14 in Appendix 15.

From these accounts one could sense several difficulties relating to the following problems:

- Lack or shortages of key materials, and
- Lack of requisite facilities.

What was interesting here was that teachers alluded to these problems even before being asked about them. At this point, the issue was about their prospects of teaching the subject in schools. They had not been specifically asked to indicate any problems. These appeared to be burning and pressing issues that could not wait although the next question was specifically about problems teachers anticipated back in their schools.

When teachers were eventually asked about the problems they anticipated when they went back to their schools trying to implement ideas learnt from their MS and MSP courses, they outlined several as reflected in Appendix 16. The whole idea was to check on the confidence of teachers regarding application of MS in teaching. The purpose of having teachers applying their knowledge of MS during MSP was to have them fully equipped with the relevant knowledge and skills before going back to their schools. There was then a need to check on their preparedness, not only to meet with success but also for anticipated problems. This was in fulfillment of the third secondary research question. Teachers were also afforded a chance to suggest possible solutions to some of the problems. Out of the 18 teachers 15 anticipated problems and 3 did not anticipate any as shown in Appendix 16. Those who anticipated problems highlighted the following:

- Financial problems generally resulting in schools failing to secure relevant materials and equipment. The root of this problem was levelled against the pressing economic problems currently prevailing in the country. For this problem, a possible solution was to seek financial support from government through the ministry of education and culture, or from the school development association. In the event of these possibilities failing, the other idea was to manage with whatever little that was available.
- Failure to teach the intended courses (MS and MSP); since it was feared some schools were going to abolish technical subjects due to the high costs involved. One possible solution here was to be as flexible as possible in terms of opting to teach any related subjects in schools. For example, they could switch over to some science related areas like physics and chemistry.
- Being allocated or assigned to teach classes comprising of weak or slow learners due to the stigma usually attached to technical subjects. A possible solution suggested here was to embark on a drive to improve the image of technical subjects in general and D&T in particular.
- Lack of instructional materials, like textbooks. No possible solution was given here, although there was mention of substitutions and improvisations wherever possible, for example teacher developed handouts and modules.
- Shortage of time to cover all the required activities. The suggestion was to manage with whatever little time that was there by making necessary adjustments wherever possible.

In fact, most of the problems outlined here could be traced back to the current economic hardships the country is facing due to the crippling sanctions. Some of the problems highlighted, were not coming up for the first time in this study. They also surfaced during the preparatory stages as shown in Table 4.5 under Section 4.1.3. Recurrence of these problems was more or less a confirmation of a situation already in existence. This also served to confirm and strengthen earlier results and findings, especially those at preparatory levels.

**Cohort '2' interviews** (As at pre-practical examination)

These interviews were conducted just before the practical examination in MSP. The guide for these interviews comprised of three major questions; mainly to do with the following key issues as shown in Appendix 8:

- How well prepared teachers felt for the oncoming practical examination.
- Anticipated relationship between MS and MSP in the oncoming practical examination, regarding the extent to which MS was going to be reflective in the examination.
- Anticipated usefulness and applicability of MS in the oncoming examination.

***The level of preparedness among teachers***

Asked how well prepared they felt for the practical examination, all the eleven teachers who had volunteered to participate in these interviews confirmed that they were prepared. The only difference was in the level or degree of preparedness, where five indicated that they were 'very well prepared'; while four were 'well prepared' and lastly, two were 'fairly well prepared'. Appendix 18 shows a summary of these profiles and the other two options for possible responses; 'lowly prepared' and 'not prepared'. The last two options were however not taken.

Apart from indicating their feelings regarding level of preparedness for the said examination, teachers proceeded to explain why they felt so (Appendix 19). In this case, the teachers' reasons and explanations were captured word for word. For example, teachers '1', '2' and '3' had the following to say:

- **Teacher 1** (3): (Fairly Well Prepared) A--I—I am prepared. I have--. We--we had some pre-requ—iste--e--e – courses like -e-e-Material Science, Engineering Science and Physics, as well as --a-a-- Chemistry. Yes. Material Science is very, very important to--to--to--e--the course, which I am to write—e--Yes to--to undertake.
- **Teacher 2** (5): (Very Well Prepared) E--- at the mean-time, I can say we are almost prepared since we did a lot of Material Science, a lot Engineering Science and currently according to what

we have done, we have made models using card and consideration of the materials is also applying in the Engineering Science we have been taught. So, we are almost there, I can say.

- **Teacher 3** (11): (Well Prepared) Yes, I can say, yes I am --- I am --- prepared because I have done some reading and so forth; together with Material Science which we have covered. I think I am well prepared for the exam tomorrow.

(NOTE: Again, the numbers in brackets are the ones that featured in the original data base as also reflecting on the rest in Appendix 19)

From the three accounts here and the other 8 outlined in Appendix 19, one of the reasons teachers gave for their reasonably high level of preparedness was that they had studied MS, whose elements/concepts they thought were going to comprise a major part of the examination. This helped a lot to strengthen the argument that they were applying their knowledge of MS in several ways to solve practical problems under MSP. From these responses, various degrees of preparedness were indicated. For example, according to the three excerpts above concerning this issue, three of such degree were 'fairly well prepared', 'well prepared' and 'very well prepared'. All the 11 teachers were prepared for the examination.

***Anticipated relationship between MS and MSP in the oncoming examination***



On the issue of the anticipated relationship between MS and MSP in the oncoming practical examination, all the eleven teachers had something to say about the extent to which they expected MS to be reflected in the examination. They also gave examples of specific cases on this issue, to support their views. A close examination of what the teachers were saying reflected a lot of understanding of the following concepts and facts: materials being arranged in particular groups in the periodic table; elements of similar electronic configuration being suitable replacements of each other in specific applications, and choosing specific materials for particular applications according to their characteristics or properties. Most of what teachers said appeared adequately relevant to justify and confirm the need to relate these two subjects; not only for the purpose of the oncoming examination in particular, but also to promote subject integration in general. All these views are outlined in Appendix 20, where the following accounts from three teachers appeared outstanding:

- **Teacher 1** (2): Very much so! E---, because there are concepts we are supposed to consider when we're designing articles and these concepts we have learnt about them in Material Science. We are supposed to know the structures of the materials, their compositions, e--- and various types which can be used as substitutes to the ---, materials which can replace each other when you cannot have the --- the ones which you want.
- **Teacher 2** (4): Yes, it comes in because--there is one aspect which--maybe we can say there are several aspects that we find in--in the design process, like--the--the research part of it, whereby you're looking at the types of materials that are required in, let's say you are given a group, you have to look at the types of materials that are required. I think that aspect is covered in Material Science, --the strength and so forth. All those aspects are covered in Materials Science, so I think Materials Science is quite of importance in the design process. E--, it is --it is quite applicable. Actually, as I have -e- already elaborated or I--I have--, you find that, there are certain aspects that you find in--Machine Shop Practice that we will have to --which we must have some knowledge of--or as a prerequisite. So, that of course, it is found in the Material Science aspect and --I think it is part of it.
- **Teacher 3** (10): I---I think the relationship is there between the two subjects. If --- I --- we were to have all the relevant or required materials and equipment this relationship would even be more effective --- and clearer. But --- but the problem is that we are likely to have problems securing the right materials and equipment. We need the right materials, we--we have to use the actual material so that at least we have to apply—Apply what we learnt in Material Science.

In order to strengthen their arguments on the relationship between MS and MSP, teachers also elaborated on how they thought MS was going to be useful and applicable during the examination. They had more to say on this issue as shown in Appendix 21 where further examples of their responses are outlined in addition to the following profiles, found outstanding to deserve attention here: .



- **Teacher 1** (3): Very much so! E--, because there are concepts we are supposed to consider when we're designing articles and these concepts we have learnt about them in Material Science. We are supposed to know the structures of the materials, their compositions, e--and various types which can be used as substitutes to the--, materials which can replace each other when you cannot have the-- the ones which you want. E--, what I can only say is that the--its relevance as in--the even stressed by our lecturer in charge for Machine Shop Practice-- Mr. Gweru-- has stressed that --'Please make sure that you consider what you learnt in Material Science for the exam which you are to undertake'. And, I think that is a point, which shows that Materials Science is much relevant as being considered by the lecturer in charge for the current Machine Shop Practice in preparation for the examination.
- **Teacher 2** (7): I look forward to seeing an examination, which really tests us on things, which we have learnt, the Material Science, -- on different materials. So, I am sure, it's going to be applicable.
- **Teacher 2** (11): Yes, it is applicable because you know in--in Machine Shop we do a lot of --we have a lot of different types of Materials so, I think yes, it is going to be very, very helpful. --Yes, I think the issue after-- in fact Material Science itself, by the time, we –we do a lot theory part of it, fair and fine, but at times--there are certain topics which like we need to go to the workshops to do some experiments to see to--exactly how they behave under specific conditions. The same also applies to Machine Shop Practice where we only make models. We end up ma--making models. We,--it would be very good for us to go into the actual workshop and make the real thing.

However despite all the positive views, teachers had queries and concerns regarding the application of MS during the examination. For example, they doubted the availability of materials and relevant equipment, following the chronic problems and/or shortages experienced during their course of studies.

Up to here, this is how far Cohort '2' Interviews went, checking on the teachers' views before the practical examination. The same teachers were later interviewed soon after the examination in order to determine their views then, as compared to those they held, just before the examination. It was hoped this would give a reliable picture of the teachers' actual experiences regarding application of their knowledge of MS during the examination, in view of what actually transpired during the examination. Therefore, interviews after the examination were a follow-up and even the tone of the questions was appropriately along those lines (Appendix 8).

**Cohort '2' interviews** (As at post-practical examination)

After the examination, there was then a need to determine the experiences of the teachers and find out whether they:



- had felt satisfied with their performance in the examination.
- had found themselves well or adequately prepared for the examination.
- had found their MSP and MS courses reflective of each other during the examination.
- had actually found their knowledge of MS useful and/or applicable during the examination.

Therefore, given these issues, results and findings accordingly went as follows:

***Degree of satisfaction with performance during the examination***

Asked whether they were satisfied with their performance during the examination, teachers confirmed in the positive. Given the various options in terms of level or degree of satisfaction, six teachers indicated that they had been 'very satisfied' while another five indicated having been just 'satisfied' (Appendix 22). This outcome was consistent with that from the pre-test interviews where the same teachers had indicated that they felt adequately prepared for the examination.

***Confirmation of the degree of preparedness for the examination***

As to whether they felt they had been well or adequately prepared for the examination, eight teachers confirmed having been 'very well prepared' while another three indicated being 'well prepared' as shown in Appendix 23. Compared to the pre-test results/findings where teachers had indicated the following: 5 – 'very well prepared'; 4 – 'well prepared' and 2 – 'fairly well prepared', the post-test outcome was a clear indication of successful preparation. The best part of the post-test results and findings was demonstrated by the movement of two teachers who had initially indicated being 'fairly well prepared' to higher levels of preparedness, where they indicated being either 'well prepared' or 'very well prepared'.

***Confirmation of whether MS and MSP had been reflective of each other***



On whether they had found MS and MSP reflective of each other during the examination, all teachers confirmed these courses being a mirror of each other. Appendix 24 shows accounts of what teachers said word for word in addition to the following examples:

- **Teacher 1** (3): Definitely, I was satisfied because we had all the--we had been given all the material roots---the information about materials and we have been exposed to some of the samples which were brought to our lectures and when we sat for the exams, especially like in Machine Shop Practice 2 which we did this semester, I did not face any problem. Everything was okay because I took everything---, every information that was available to me.
- **Teacher 2** (6): As a comment? A-a yes---I think---I think--they were well--well organized---more than it---because, if you look at Material Science, we did Material Science---last---last semester---last semester---last semester---and then we got our Machine ---Shop this semester. So already, you can see that---what---what we---what we learnt in Material Science we were applying this in what---this semester in what---in Machine Shop---which was quite okay---which was excellent---because we would have to select this material on this and that.
- **Teacher 3** (8): I think there are a number of aspects, which we find in Machine Shop Practice, which---if one had not known in theory about materials---, which we find in Material Science, ---I think it would be very difficult to come up with a---projects, let's say, in Machine Shop Practice, just because there are a number of aspects which you have to know before you start your Machine Shop Practice. Yes---yes---because we are saying then in Machine Shop, you are using a variety of materials, so you should know the characteristics of various materials so that you have got a wide choice of materials to choose from and also to choose the appropriate materials for the projects you'll be working on. Like I have said before, in Machine Shop Practice, we are looking at a

number of materials that we use on various projects and in order for us to know the various materials with their properties, characteristics and the like, you need to know---you need to have this Material Science. So I think these two subjects, ---what can I say--have, to run concurrently.

- **Teacher 4** (11): Yes, we used some of the things we learnt in Material Science, especially the metal. The exam was quite challenging. The design task, which we were given, was quite challenging and we really had to think, to come up with a good idea. Oh yes, that knowledge on Material Science was beneficial because as a woodworker, the project I was supposed to do was going to use metal. Material Science should always come first followed by Machine Shop Practice so that we get familiar with the materials that we then use later in Machine Shop Practice. The program was quite okay, starting with the study of materials before using them later in Machine Shop Practice.

***Confirmation of whether MS had been useful/applicable during the examination***

On whether they had actually found their knowledge of MS useful and/or applicable during the examination, all teachers confirmed in the positive. Appendix 25 shows word for word accounts from seven teachers in addition to the following outstanding examples from four teachers on this issue:

- **Teacher 1** (1): All right, e--we have written our examination on MSP and Design and we found out that -e- for you to be able to tackle th--e, such a test, you would need great knowledge about MS. So, I think this course of MS was very useful and it encouraged us and developed us a lot in accomplishing our examination. Well--, I think--think the structure of the course itself was very good, it was highly organized, that is, the MS. It was highly organized and it encouraged us to learn more and we actually managed to learn on our own--.
- **Teacher 2** (5): Ya-a ---, MSP --- it was a good paper actually because we had a chance to apply what we have learnt in MS, especially when we did our market research. We went to St. Giles and we actually had a chance to look at some of the materials, which we learnt about and are actually in use.
- **Teacher 3** (7): Right--a-a- I'll have to say, from my experience, what we did in MS can be very, very useful to any technologist or designer because we're saying, the moment you know about materials you are very assured of what you are going to do in the practicals, that is in MSP. So --I would like to advocate that wherever there is some theory being learnt concerning materials, there should be--an immediate comprehension on the practical part of it so that students can actually prove to themselves that this is useful and this is not.
- **Teacher 4** (11): Yes, we used some of the things we learnt in MS especially the metal. The exam was quite challenging. The design task, which we were given, was quite challenging and we really had to think, to come up with a good idea. Oh yes, that knowledge on MS was beneficial because as a woodworker, the project I was supposed to do was going to use metal.

Note**:** Again, just like on all previous accounts, the numbers in brackets are the original ones in the relevant data bases just like the one in Appendix 25 in this case.

An overall comparison between the pre- and post-practical examination results and findings shows very positive developments throughout the interviews. All the statements from all interviews were adequate evidence and proof of teachers actively applying their knowledge of MS in their learning of MSP. A lot of what they said justified the need to check for further confirmation and evidence from their records and accounts in design folios.

**Content evaluation of design folios**

Apart from being drawn from interviews, more evidence of teachers applying their knowledge of Material Science (MS) in solving practical problems under the Machine Shop Practice (MSP) course immerged from records and accounts in their design folios. Teachers compiled these folios during the course of their practical activities under MSP. Evidence from these documents was obtained through 'content evaluation' whereby each folio was scrutinised thoroughly. Table 3.3 shows a matrix representing the criteria used to identify and locate traits of MS in these documents. While evidence from interviews was obtained through the spoken word, that from design folios was through the written word.

Besides seeking evidence, content evaluation(s) were also considered to be ways of confirming the various claims teachers had made in their responses to the various questionnaires and during interviews.



In their responses in questionnaires and during interviews, teachers had claimed having applied their knowledge of MS in various ways under MSP, especially during their practical activities in workshops. As teachers answered questions in questionnaires and during interviews, one could have an idea of their thoughts or views, regarding knowledge of content in MS and instructional practice in D&T. In the case of questionnaires and interviews, teachers were aware or had a rough idea of what was required of them in their answers. Although information obtained could generally be assumed to be reliable and valid, the fear was that teachers could be tempted to say something in a way they assumed the researcher expected of them. Therefore to take care of such possibilities and the associated fears, it was necessary to find out more of the teachers' thoughts from not so salient sources, such as the design folios where teachers recorded issues and events as they encountered or experienced them naturally in their daily activities in workshops since these folios were actually journals.

From the 36 design folios that were collected and evaluated, there was adequate evidence showing that teachers made use of their knowledge of MS in solving practical problems under the MSP course. This surfaced from the notes they compiled in these documents, going by the various sections. The analysis of information in these folios went as illustrated by Figure 3.18, showing data for folios 1 to 8 and Appendix 28, showing data for folios 9 to 36. The process involved going through all the notes and identifying specific points at which one could have evidence of teachers having applied their knowledge of MS in solving practical problems in the various activities under MSP, as expected in D&T.

Although the process of making sense out of the data obtained from the design folios was such a sticky affair as indicated in Chapter 3, the two routes described under Section 3.5.7 were effective and culminated in the results and findings respectively presented in tables 4.13 and 4.14. Of the two tables, the former resulted from the first route where scores ranged from a minimum of 10 to a maximum of 37 and the latter came out of the second route with scores ranging from a minimum of 6 to a maximum of 189. As explained in Chapter 3, while the first route involved one following the profiles in individual folios across all sections (1 to 7), the second was about going section by section, from folio 1 to 36 (Figure 3.18 and Appendix 28). Given this background, there was need to establish a system/systems of interpreting the data. This is where the respective scales used in tables 4.13 and 4.14 came in.

On the one hand, the main purpose of the mechanism in the scale illustrated in Figure 4.11 was to check on whether all teachers were in any way applying their knowledge of MS in solving practical problems in their activities under MSP, going by all the records in all the sections of the folio, from 1 to 7. In this case the focus was on individual teachers and their respective folios. At the end, one would then check on how many folios reflected specific levels as shown in Table 4.13. The overall range of a minimum of 10 and a maximum of 39 meant the totals of scores representing incidents of the application of MS in each folio.

On the other hand, the second scale involved going longitudinally, section by section, for all the 36 folios. Figure 3.18 and Appendix 28 show the sense behind the whole orientation here. Therefore, the minimum of 6 and maximum of 189 scores in Table 4.14 is about the total of scores accumulating for a particular section adding up for the 36 folios. For the purpose of analysis, one would then check on which section(s) was the minimum application of MS achieved and in which section(s) was there maximum application.

These scores were in each case, actually totals for the 36 folios following each section from Folio 1, right up to Folio 36. This was the case for all the sections across the board, from 1 to 7 (Table 3.3). Table 4.14 shows specific score profiles per range, fitting within the relevant sections of the design folio. The main purpose of the information in this table was to find out in which sections of the folio teachers were applying their knowledge of MS to specific levels. The extent to which teachers applied their knowledge of MS as reflected in the folios, depended on the stage of the design process, which was in turn also represented by sections 1 to 7 (Figure 3.18 and Appendix 28).



**Table 4.13** Results and findings according to the first scale

| Score Range | Level | No. of Folios |
|---|---|---|
| 1 – 9 | Very Low | 0 |
| 10 – 14 | Low | 5 |
| 15 – 20 | Moderate | 13 |
| 21 – 24 | High | 10 |
| 25 – and above | Very High | 8 |

The results and findings in Table 4.13 show that, in one way or another, all teachers applied their knowledge of MS in solving practical problem during their activities in the MSP course. The only difference in this case however, has been the extent and level of that application, depending on individual teachers.

**Table 4.14** Results and findings according to the second scale

| Score Range | Level | Folios Section(s) |
|---|---|---|
| 1 – 20 | Very Low | 1 |
| 21 – 50 | Low | 4 |
| 51 – 100 | Moderate | 2 and 5 |
| 101 – 150 | High | 3 |
| 151 – and above | Very High | 6 and 7 |

The evidence in Table 4.14 clearly shows that the application of MS during MSP as recorded in the design folios varied in intensity, depended on the various sections. While there was more evidence of application in some sections (for example in sections 6 and 7), there was much less in others (for example sections 1 and 2).

Having achieved an overview of the picture emerging from tables 4.13 and 4.14, one could sum up the general observations and say that there was adequate and satisfactory evidence of teachers really applying their knowledge of MS during their MSP course, despite the differences in the intensity of that application. All the bits and pieces of evidence gathered here, leading to the results and findings presented in this part of the study have mainly served to confirm and qualify most of the claims made by teachers in questionnaires and during interviews. Teachers claimed that they had found their learning of MS profitable in improving their understandings of materials in terms of properties and applications. They also claimed having found their knowledge of materials applicable in solving practical Design and Technology (D&T) related problems during their various activities in MSP. Another earlier observation, also confirmed by the results and findings here was the drastic shift in the perceptions of teachers, where they initially exhibited perceptions that were opposed to most of the cardinal principles underlying D&T and ended up in a complete turn around of events resulting in more positive perceptions (Table 4.8).

Developments under Section 4.3.2, where findings indicated teachers exhibiting low levels of understanding on selected concepts to do with MS before the course and ended up with much higher levels of understanding after the course were also proven and confirmed through findings from the design folios. Most of the activities leading to the compilation of these documents were observed during class and workshop activities. Teachers were actually observed engaging in various practical activities, including the compilation of the said folios. From a phenomenological and humanistic perspective, as propounded by Schubert (1989) and Smyth (1989), it was envisaged that this would be one of the mechanisms used to judge or determine the effectiveness of the instructional materials developed in this study given the purpose as implied even by the tone of the topic.

Having looked at all the results and findings presented here, it is now time to move onto Chapter 5, where the relevant conclusions have been drawn and discussed, specifically focusing on their implications within the parameters of this study.

# Chapter 5

# SUMMARY, CONCLUSIONS, DISCUSSION OF CONCLUSIONS AND THEIR IMPLICATIONS, AND RECOMMENDATIONS

In this last chapter, the task is to summarize the study, draw conclusions and discuss their implications before making suitable and appropriate recommendations where applicable and necessary.

## 5.1 SUMMARY

### *5.1.1 Focus and purpose of study*



As illustrated by the methodological framework in Figure 3.1, this study was approached from two main angles, namely; 'development of the curriculum/instructional resource package' and 'the research component'. Both angles were guided by Ally's (1997) instructional design model, which formed the foundation of the whole study. While the former was about preparatory investigations during the early part of study, the latter was about addressing the three secondary research questions, based on the primary research question.

**Focus on preparatory investigations and development of the curriculum package**

Focusing on Material Science (MS), within the context Design and Technology (D&T), preparatory investigations led to the development of an exemplary course of studies, where teachers were deliberately involved in specific ways at various levels. For example, apart from being valuable sources of information on their problems and/or professional needs, regarding content in MS and instructional practice in D&T, they also participated actively in the formative and summative evaluation of the instructional materials. This level of participation meant teachers were being actively involved in the identification of the relevant content areas and items for course development.

Some of the teachers, particularly those who volunteered to be resource-persons, also took part in the actual teaching of the various topics in the course outline. However, looking back now, one could have wished to see them involved in the actual writing and production of the instructional materials. This was the wish from the beginning, but due to several technical and logistical problems, this was not possible. Chief among these problems, were those relating to two main factors; time and cost. For example, involvement of such a magnitude was going to require more time and resources in order to bring teachers to a reasonable level of skills development. Therefore, that dimension was ruled out and declared something outside the scope of this study, despite all the good intentions and benefits that could have come with it. This did not however mean a loss of everything. The extent to which teachers were involved still meant a great deal in terms of their role and influence. Even those limited contributions made at the various levels outlined below, were enough to make an overall positive impression.



***Teachers as sources of information***

Being major players in this study, teachers were given several opportunities to indicate and express their needs and interests in terms of professional growth. And indeed, they provided a lot of valid and reliable information. Such information was very useful since it helped to inform the study, regarding decision making on issues relating to: content identification, content delivery, technology selection and the choice of instructional /learning strategies. As sources of information, teachers influenced the study in a big way. Even the activities built into the study were determined here. Teachers played this role in various ways. For example, there was a need to inform the study about their: level of preparation during initial teacher education/training, interests and priorities in terms content areas, and views/opinions on anticipated logistical problems or difficulties, as they imagined trying to teach aspects of D&T back in their schools. Teachers indicated those areas in which they felt adequately prepared to teach and those in which they felt they had not received adequate preparation during their initial teacher education and training.

***Formative evaluation of the instructional materials***

By responding to the Formative Evaluation Questionnaire (Questionnaire ‘C’), the 45 serving-teachers belonging to Intake 1 participated in the content evaluation of the various modular units, comprising the instructional materials. This allowed teachers to make comments and suggestions on various items in order to improve the materials before implementation with Intake 2. Typical examples of areas improved this way included: content items, unit introductions, unit summaries, unit tests, module tests and even the instructional strategies. This is how teachers influenced the curriculum package at this stage.

***Summative evaluation of the instructional materials***

When they responded to the Summative Evaluation Questionnaire (Questionnaire ‘D’), the 40 serving teachers belonging to Intake 2 participated in the evaluation of the whole instructional  programme at the core of this study. Being the continuation of a process commencing from formative evaluation, the exercise at this level helped to consolidate the influence of teachers upon the curriculum package. According to Ally’s (1997) instructional design model, activities at this level were part of the last stage following the implementation of the instructional materials.



Responses during the evaluation of individual units at formative level appear to have contributed towards improvement of the whole course, resulting in the positive image of the curriculum package witnessed at this level. This was another avenue through which teachers influenced events in this study, although most of their views, opinions and suggestions were considered to be part of the improvements that could be recommended for the future, specifically focusing on further development of the curriculum package.

***The role of teacher as resource-persons during the main part of the study***

Out of the 45 serving teachers in Intake 1; 44 volunteered to train as resource-persons, 13 qualified and 9 eventually partook in the actual teaching of the various topics in the course outline. Since teachers designed their own schemes of work and lesson plans, one could argue that their activities had any influence in the running of the course. In their individual ways of thinking and approaches to instruction, these teachers are likely to have made an impression on the teaching and learning processes in this study. In fact, there was a sense in which this process depended on the perceptions, understanding and knowledge of these teachers, regarding content in MS and instructional practice in D&T. For example, as they planned their lessons and the associated activities, they obviously had to interpret content items in order to make meaning out of them and by so doing, influencing events during this study.

Up to here, this is as far as one could go, focusing on preparatory investigations relating to the design, development and production of the curriculum package. From here, focus then shifted towards the research component of the study, where the implementation phase, acted as an overlap between the two components; preparatory investigations and research.



**Focus on the main research component of the study**

This part of the study commenced with the implementation of the instructional materials, involving the 40 serving teachers belonging to Intake 2. Investigations at this stage were conducted within the limits of the primary research question, in conjunction with the three associated secondary research questions. All these questions were addressed at three main levels, namely; Pre-MS, Post-MS and Post-MSP.

To determine the effect of the MS course on the perceptions, understanding and knowledge of teachers, regarding content and instructional practice, there was need for a special kind of evaluation. This involved a pre- and post-test mechanism, where ‘Learner Analysis’ was isolated for the pre-test while ‘Summative Evaluation’ went with the latter, going by the instructional design model in Figure 2.2.

With the support of other instruments and mechanisms like, interview and observation guides/schedules, the main instrument for investigations here was the Pre & Post Test Questionnaire (Questionnaire 'A2"). Apart from determining the perceptions, understanding and knowledge of teachers, this questionnaire was also designed to determine the extent to which teachers felt confident to handle specific content items of the course, in the event of teaching MS at 'A' Level. Teachers were also expected to reflect on their perceptions, understanding and knowledge of specific concepts in MS as they solved practical problems during the MSP course. This meant putting theoretical knowledge into practice. These expectations were in view of the primary and secondary research questions, rooted in the three-fold challenge relating to the professional development of teachers, where the intention was to:

- increase scientific knowledge in order to approach the teaching of D&T from a scientific perspective/orientation.
- enhance the competence of teachers in solving practical D&T problems, where practical skills are guided by scientific knowledge and principles.
- Increase the understanding of how to teach pupils to solve technical problems in D&T by putting theoretical knowledge into practical application.

As explained in chapters 1 and 2, such a challenge required a paradigm shift, calling for the life-long professional development of teachers, as has become the trend in many other fields.

Given this background, at the pre-test level of this study the idea was to establish the starting point in terms of what perceptions, understanding and knowledge teachers held, regarding content in MS and instructional practice in D&T. One needed to have an idea of the status of the teachers on these factors as they came into the programme. This outcome was later compared to what the teachers ended up with after the MS and MSP courses. The purpose of the Post-MS run of the questionnaire was to determine the impact of course on the perceptions, understanding and knowledge of teachers, as compared to the pre-test experience.

Lastly, after MSP, one wanted to check on the value that could have been added by the application of MS in solving practical problems, as teachers relied on the perceptions and knowledge/understanding they held at that point in time, regarding content and instructional practice in D&T.

### *5.1.2 An overview of methodological issues in general*

An overview of methodological issues in this study shows the main participants comprising two intakes (45 in Intake 1 and 40 in Intake 2) of serving teachers in the Bachelor of Education (B.Ed.) degree program from the Department of Technical Education at the University of Zimbabwe. Currently qualified to teach up to 'O' Level, these teachers had the potential to be staff developed for teaching aspects of D&T at 'A' Level, where among many aspects, Material Science (MS) was the main subject of focus. Enrolled in two programs, the former group had 23 candidates under Wood Technology and Design (WT&D) and 22 under Metal Technology and Design (MT&D), while the latter had 21 and 19 respectively.

To address the research questions, the following instruments and/or materials were designed, tried/tested and implemented: the syllabi check-list, instructional resource package, questionnaires, interview guides and observation guides. The content evaluation of design folios enabled one to check on the extent to which teachers had applied their perceptions, understanding and knowledge of MS in solving practical problems under MSP, as expected in D&T. Since this study was mainly qualitative, I (as researcher) became part of the instrumentation, as recommended by Patton (1990). Above all, rigorous measures were taken to ensure the validity and reliability of the instruments and all the related activities. Such measures included; piloting the instructional materials with Intake 1 (formative evaluation) before implementation with Intake 2, triangulation of approaches at various levels and seeking the independent opinions of my promoters and colleagues in the GRASSMATE Programme, on various issues requiring informed decision making.

Data were analyzed respectively through various methods, depending on the nature of data; either quantitative or qualitative and whether for the developmental part or the research component of the study. This was all within the confines of the methodological framework in Figure 3.1, which in turn led to the respective categories of results and findings summarised below.

### *5.1.3 Results and findings*

In line with the purpose and focus of the study, results and findings were accordingly categorized into; those for the developmental part and those for the research component. While the former were drawn from preparatory investigations of the study, the latter were based on the three secondary research questions, as illustrated in Figure 3.1.

**Key results and findings from the developmental component of the study**
(Preparatory investigations)

Investigations at this level involved the development of the instructional materials used in this study; a process that called for several measures and steps, mainly aimed at determining the needs of teachers, in terms of professional development.

Although a major part of investigations here involved the 45 serving teachers from Intake 1, there was a point at which the 40 teachers from Intake 2 came in, thereby creating a kind of change-over from one intake to the other. While the first intake concluded activities with the formative evaluation of the instructional materials, the latter commenced with the implementation that led to the summative evaluation of the same materials. This is the background in which the results and findings for this study have been presented in Chapter 4.

However in terms of focus, during the developmental part of this study, investigations were restricted to activities where the following had to be determined:

- Relationship between the ‘A’ Level D&T syllabus and the ‘O’ Level Wood/Metalwork syllabi

- The foundation of ‘A’ Level D&T within ‘O’ Level Wood/ Metalwork syllabi
- Level of preparation during initial teacher education and training
- Views and opinions on areas for possible course development in the proposed in-service programme
- The extent to which teachers were willing to act as resource-persons during this study
- Logistical problems/difficulties teachers anticipated in teaching D&T at ‘A’ level
- Content items for the proposed curriculum package

In a bid to identify what specific items in the ‘A’ Level D&T syllabus could have been familiar to the teachers, in view of their experiences teaching at ‘O’ Level, the completed check-list in Appendix 1 was used to cross-check the various aspects in this syllabus against those in the ‘O’ Level Woodwork and Metalwork syllabi. This was also a way of *relating these three syllabi*. The patterns that emerged showed the ‘A’ Level D&T Syllabus (2002 version) being very closely related to the two ‘O’ Level syllabi, despite a few areas of slight differences. According to the data summarized in Figure 4.1, several aims, objectives and content items in the ‘A’ Level syllabus also appeared in both ‘O’ Level syllabi, thereby demonstrating the close relationship between these three syllabi. Since the MS course, was drawn from items in the ‘A’ Level syllabus, these indications helped to give a clue of what teachers could have been familiar with, and what could have been totally new to them.



Given the relationship between the above mentioned syllabi, the assumption was that, *the foundation of the ‘A’ Level D&T could be located within the two ‘O’ Level syllabi*; a situation typical of the Zimbabwean context. What happens at ‘O’ Level, for most subjects if not all, is supposed to be the foundation of what later goes on at ‘A’ Level. Therefore, D&T being a technical subject with roots in subjects like Woodwork and Metalwork, what happened at ‘O’ Level was expected to be *a foundation for D&T at ‘A’ Level*. Effectively, what teachers got familiar with at ‘O’ Level, regarding the teaching and learning of D&T was going to provide the starting point of their new experiences teaching the subject at ‘A’ Level. This was important in order to know where we were coming from and where we wanted to go in terms of decision making on what elements to include in the intended instructional materials. This meant starting from the known, before going into the unknown, which in this case, implied taking advantage of the teachers' previous experiences regarding what they already knew about D&T, particularly as an approach.

In Part (C) of the Learner Analysis Questionnaire (Questionnaire 'A') teachers indicated several areas that they thought would be pre-requisite to what they were going to encounter in their teaching of D&T at 'A' Level. These included; Theory of D&T, Material Science, Mechanisms, Motion, Structures, Nature of Materials, Materials and their Properties, Materials Processing, Materials and Process Selection, Pneumatics, Hydraulics and Graphic Communication.

In order to determine the *level of preparation during initial teacher education and training,* teachers were asked to indicate the extent to which they felt their initial teacher education and training had prepared them to handle specific elements of the existing 'O' Level Wood/Metalwork syllabi when assisting pupils in their learning of D&T.

According to their responses on (B)1 of the Learner Analysis Questionnaire (Questionnaire 'A'), which required them to indicate the aspects they felt adequately prepared to teach and those where they felt inadequate, indications were that teachers felt happy with their teaching of the Theory of D&T and Graphic Communication. They were however not quite comfortable with the rest of the elements, which included Material Science, Evolution and Nature of Materials, Materials and their Properties, Materials Processing, Mechanisms and Motion, Structures, Pneumatics and Hydraulics. Most of them indicated that they were either, 'not quite prepared' or 'not at all prepared'. There were also a few who were undecided.

Being major players in this study, teachers were also closely involved and consulted in order to have an idea of their *views and opinions on areas for possible course development in the proposed in-service programme*. This way, teachers had an opportunity to contribute towards the identification of the content areas that could be considered for possible development into the relevant instructional materials. According to the design of Questionnaire ‘A’, teachers were able to make such contributions in specific parts and items (Figure 3.2 and Appendix 2). For example, their priorities and preferences, in terms of professional needs became evident, starting from ‘learner analysis’ where they showed their areas of strength and those of weakness from initial teacher preparation. Table 4.1 shows data from Item (B)1 of this questionnaire.

More of these opinions were indicated in response to Part (D)1 of Questionnaire ‘A’. Specific areas were proposed in view of the issue of importance and according to the question of relevance and appropriateness in the Zimbabwean context. The choices made here also appeared to confirm those areas teachers found inadequate in terms of preparation from their initial teacher education and training. This is where items (B)1 and (D)1 in this questionnaire appeared related. They both looked for the shortfalls that would in turn reflect the levels of mismatch between teacher preparation and realities in schools.

Specifically, teachers indicated that the following areas were important and they wanted to see them included in the proposed in-service program: Materials Science and its related components, Structures, Mechanisms and Motion, Electricity, Electronics, Pneumatics and Hydraulics. Table 4.3 shows more details on this issue.



On their *willingness to act as resource-persons during the course of this study*, only 1 of the 45 serving teachers in Intake 1, appeared not interested. However, this individual was later among those who showed an interest in teaching the ‘Theory of D&T’. The majority of the teachers were interested in, or rather prepared to teach this topic. They were responding to Part (E)1 of Questionnaire ‘A’, which appeared closely related to Part (B)1, regarding the essence of what was being asked for. These parts of the questionnaire were actually triangulating and corroborating each other. The same areas were either; highly or lowly rated in these two components.

The other topics where teachers showed an interest were, Mechanisms, Motion and Graphic Communication.

Teachers were however not quite comfortable with the rest of the elements in the course outline. These included Material Science, Evolution and Nature of Materials, Materials and their Properties, Materials Processing, Thermodynamics, Fluid Mechanics, Electricity and Electronics, Analogue Signal Processing, Control Systems, Computer Control, Structures, Pneumatics and Hydraulics.

In order to understand the realities of the situation teachers were going to work under in schools, in Part (F)1 of Questionnaire ‘A’, they were asked to indicate what *Logistical problems/difficulties they anticipated in their teaching of D&T at ‘A’ level*. According to their responses, as shown in Table 4.5, teachers anticipated problems relating to the lack of literature, relevant equipment, relevant materials (consumables) and support from teachers of other subjects. They however did not foresee problems relating to the lack of: facilities, time on the time table, and safety. This was quite encouraging, particularly regarding facilities like workshops. It was indeed pleasing; and to an extent, surprising to have teachers expressing satisfaction on facilities. This information was very important in the identification of content and in selecting the related ‘delivery technology’.

After the various investigations described above, *the resolution was to design and develop an exemplary course that became central to this study*. Material Science (MS) emerged as the most preferred option and was chosen from among several other possible areas of D&T. All the responses and the associated trends resulting from investigations here had far reaching consequences for the whole curriculum package. For example, there was no need of including those areas where teachers had indicated being comfortable in, regarding teaching. Instead, it was those aspects where they expressed wide-spread dissatisfaction that one needed to seriously consider for inclusion in the package. This was also mainly in view of the teachers’ views and opinions indicating their preferences on what areas they wanted to see included in an in-service course designed for their professional development. In addition to these views, further investigations involving a comprehensive literature search led to the identification of specific recommended elements for the intended instructional resource package in MS. The course comprised of seven units, with the following topics: 1. Three families of engineering materials; 2. Metallic structure (the unit cell); 3. Effects of stress and temperature on simple metal structures; 4. Engineering alloys; 5. Steel, cast iron, ductile iron and malleable iron; 6.

Composite materials, including concrete and wood, and 7. Plastics (high polymers). Appendix 6 shows more details on the various aspects covered under each topic.

***The production and application/implementation of the instructional materials***

Following production, the instructional materials were formatively evaluated before implementation and summatively evaluated after implementation. Linking the production and the implementation of the instructional materials in this manner meant the creation of a bridge between the preparatory and the main findings in this study and by so doing, bringing the major activities of the two main samples of participants together.

***Formative evaluation of the curriculum package*** went, unit by unit with the Formative Evaluation Questionnaire (Questionnaire 'C') being completed for every one of the seven units. The whole idea was to determine the views and opinions of teachers on the various modular units.



Generally, all the individual units were either very well, or reasonably well received. From most of their responses, teachers were very much in agreement with most of the statements, thereby suggesting their satisfaction with the respective issues implied therein.

Of all units, 4 and 7 were the best received with mean scores ranging well above **4.00** on the 5-point Likert-like scale, where the lowest was **4.21** and the highest **4.56**. Teachers were satisfied with all the items here and no issues of concern whatsoever, were raised.

However, for the rest of the units teachers had two or more issues of concern where they appeared unhappy about specific items. For example, they were generally not happy about some of the unit introductions, unit summaries, unit tests, self assessment mechanisms, reflections and practice activities (in terms of clarity and content coverage).

Teachers expressed satisfaction with aspects relating to the; relevance of the various topics, structural design of the various units, statement of objectives, accommodation of the various objectives in the content, relevance and appropriateness of content items, relevance or usefulness of group activities and usefulness of self-assessment activities.

All the concerns raised by teachers from Intake 1 during the formative evaluation were taken seriously and relevant improvements were effected before implementation of the materials with teachers in Intake 2.

***Summative evaluation of the curriculum package*** followed implementation of the materials with the 40 serving teachers in Intake 2. As already noted under Section 4.2, Sub-section 4.2.1, the summative evaluation of this package was at two levels. Initially, teachers responded to the Summative Evaluation Questionnaire (Questionnaire 'D'), designed to evaluate the whole programme of instruction in terms of suitability of the materials. Later on, under the main part of the study (research component), evaluation continued through mechanisms meant to check on the effectiveness of the whole instructional package or programme, in terms of impact on the perceptions, understanding and knowledge of teachers, regarding content in MS and instructional practice in D&T (see key findings on the research component below).

Going by the instructional design model in Figure 2.2, all investigations at this level were in line with the last stage, concerned with the 'Implementation and Summative Evaluation' of the instructional materials.



From the pattern of responses that emerged, the whole package of instructional materials appeared to have been widely received. Responses during the evaluation of individual units were a useful contribution towards the improvement of the whole course. Of all the 15 items in the questionnaire, 14 had mean scores well above 4.0 on the 5-point Likert-like scale. While the lowest was 4.3, the highest was 4.7, suggesting teachers holding very high opinions on the issues in question. These indications showed that teachers found the: whole instructional package relevant for D&T, overall aims clear and easy to follow, unit objectives easy to follow, aims and objectives well accommodated in the content, course outline well structured and easy to follow, course useful for teaching D&T, units well introduced and summarized, practice/group activities useful, unit tests useful and materials comprehensively covering the whole course.

However, despite all the positive responses on 14 items in Questionnaire 'D', one item gave a slightly different picture, going below 4.0. A mean score of **3.6**, with a standard deviation of **1.2** reflected a lot of mixed views, where a reasonably high number of teachers were not satisfied with the amount of time allocated for the module. They felt 60 hours were not enough, given the amount of work and then proceeded to propose; 75, 80, 100 and 120 hours. Among these suggestions on possible course duration, the last was the most popular with the majority of the teachers (28 out of 39).

**Key results and findings from the research component of the study** (Main research activities)

Being the component under which summative evaluation continued as already observed in Sub-section 5.1.1, the main instrument used in conjunction with interview/observation schedules and folio content evaluation mechanisms was Questionnaire 'A2'. This questionnaire was based on the pre- and post-test design, where results and findings were drawn from three runs, corroborated through interviews, observations and folio evaluation.



This phase of the study followed the above mentioned preparatory investigations that culminated in the production of the instructional materials at the core of this study. It commenced with the distribution of Questionnaire 'A2' at pre-test level, where all the 40 serving teachers in Intake 2 responded as soon as they joined the programme and just before the MS course. In terms of results and findings, the picture that came out at this level was totally different from what latter emerged after both, MS and MSP, as detailed below. According to the three secondary research questions guiding events in pursuance of the primary research question, the intention was to determine the following:

- What perceptions of specific aspects of Design and Technology as an approach that teachers held;
- What knowledge/understanding of specific concepts in Material Science teachers held in relation to the teaching and learning of Design and Technology; and,

- The extent to which teachers were competent to apply their knowledge of Material Science in solving practical problems under the Machine Shop Practice course.

The administration of Questionnaire ‘A2’ on three counts (Pre-MS, Post-MS and Post-MSP) allowed one to establish the perceptions and knowledge/understanding of teachers at entry and exit levels; that is, as they came into the programme and as they left.

To determine the ***perceptions of teachers on D&T as an approach***, 15 items/statements based on the same principles/ideas as those that guided the design and development of the instructional materials were used. These principles included; problem solving, life application, knowledge integration and transfer, hands-on experimentation, no theory specification when engaging pupils in learning activities, minimal laboratory/workshop instruction, and group learning. The purpose of Part (B) in the Pre- & Post-Test Questionnaire (Questionnaire ‘A2’) was then to check on the perceptions of teachers regarding these ideas. And, the extent to which they agreed or disagreed with them at the three levels helped to indicate their perceptions on specific ideas at a particular point in time.



Initially, teachers exhibited perceptions that were generally opposed to the principles of D&T as an approach. However, after the MS course, there was a marked difference resulting in more positive perceptions. The picture was even brighter after MSP. In essence, the design of the statements in Part (B) of Questionnaire ‘A2’ was such that, there were those on which low mean scores were the ideal on the one hand and others on which high scores were ideal on the other hand, if teachers had the right orientation towards the philosophy of D&T. Now, as it turned out, the opposite was the case on most of the statements, if not all, at pre-test (Pre-MS) level, only to change at post-test levels.

The study captured the perceptions of teachers at the three levels already identified as pre-test (Pre-MS), Post-MS and Post-MSP. What was then important, was to clarify the patterns of perceptual changes and comparisons immerging from among the specified levels. This is where the initial perceptions of teachers were found to be totally different from what they ended up with on most of the cases, as already noted. A comparison of the perceptions of teachers across the three runs of Questionnaire ‘A2’, showed a marked difference, especially between the pre-test (Pre-MS) and the Post-MS scores. A more or less similar situation goes for the comparison between the Pre-MS scores and those after MSP, considering the equally wide gap across the board. The MS course made a great difference in the development of positive perceptions towards D&T. This was ample evidence of a lot of learning having occurred. Teachers ended up seeing issues differently in relation to the teaching and learning of MS within the context of D&T, compared to way they started.

To determine the ***knowledge/understanding of teachers on concepts in MS***, parts (C) and (D) of the Pre & Post Test Questionnaire (Questionnaire ‘A2’) were used in addition to performance during the final examination in MS. These two parts were concerned with ‘knowledge of materials’ and ‘level of confidence on topics’ adapted from the course. While Part (C) was the main mechanism designed to determine the levels of understanding at the three pre-determined stages (Pre-MS, Post-MS & Post-MSP), responses to Part (D) and performance in the examination were there to cross-check or corroborate the results and findings from Part (C).



Although teachers started with very low levels of understanding on the 30 selected items in Part (C) and very low confidence on the various topics and sub-topics in Part (D) of Questionnaire ‘A2’ at pre-test level, they later exhibited higher levels of understanding and confidence at the two post-test levels (Post-MS and Post-MSP). They also performed reasonably well during unit-tests and during the final examination in MS where an overall average mark of 65%, inclusive of coursework, was earned from the 40 entries, representing the serving teachers in Intake 2 (2003–2004). In this case, the highest mark was 80% while the lowest was 53%.

Like the trend on perceptions, the gap between indications from the Post-MS and Post-MSP runs of Questionnaire ‘A2’, on components (C) and (D) was not as wide as that between the pre-test (Pre-MS) and either of them. In both cases, although teachers started from a very low ebb regarding knowledge and confidence on specific items, the MS course contributed immensely towards the marked improvement witnessed between the pre-test and the two post tests. After MS, teachers demonstrated generally much higher levels of scientific knowledge and understanding. From the way teachers responded, one could see the impact that the course had had on their scientific knowledge/understanding of materials. This was in fact, confirmed by the final assessment in MS.

Knowledge of MS also proved useful during MSP, where teachers became better informed in their application of materials. The increase in knowledge and understanding of the concepts in Part (C) of Questionnaire 'A2' is most likely to have contributed towards the trend where teachers became more confident to teach the seven topics and their respective sub-topics in Part (D) of the same questionnaire. This was in anticipation of teaching MS at 'A' Level, where the main topics included: Engineering materials in general; Metallic structures; Effects of stress and temperature on metals; Engineering alloys; Cast iron, ductile iron and malleable iron; Composite materials and Plastics. By design, each of these topics related to specific statements in Part (C). Initially teachers lacked the confidence to teach these topics and indications were that they needed a lot of help if they were to assist pupils/students effectively in their teaching. However, after MS, there was a general gain in confidence, which seemed to have been maintained and reinforced even after MSP. Post-test scores in this case showed that teachers gained a lot of knowledge/understanding from the MS course and from the way it was integrated with MSP.



To cross-check and confirm their newly acquired perceptions and knowledge/understanding regarding content in MS and instructional practice in D&T, there was a need to determine the extent to which teachers ***applied their knowledge/understanding of MS in solving practical problems under MSP***. This was done at various levels as teachers were observed working in workshops, manipulating equipment and materials in the process of solving specific practical problems. Evidence in design folios showed teachers making informed decisions in their choice of materials for particular applications, based on their nature both, chemically and physically. Some of the choices they made could hardly have been possible without adequate knowledge of the scientific principles behind materials. All these developments appeared to explain the high levels of confidence teachers ended up with after both, MS and MSP. Data from interviews also helped to corroborate and confirm these developments since teachers claimed to have found their knowledge of MS applicable in their practical activities.

From the *first cohort of interviews (**Cohort 1**)*, all teachers acknowledged the relationship between MS and MSP and proceeded to describe how they had applied their knowledge of MS to solve practical problems or explain phenomena under MSP. This way, they confirmed having had a chance or chances to apply their knowledge of MS in their learning of MSP. They gave examples of situations under which such opportunities had occurred, thereby reinforcing the fact that they had actually found their knowledge of MS applicable and useful in real problem solving situations. However, in their evidence and elaborations, some of the teachers also reported encountering problems in their efforts to apply MS in their learning of MSP. Seven out of the 18 teachers who were involved here reported problems that included; lack/shortages of key materials on the local market, lack funding, some of the assigned projects not being challenging enough and inadequate time for all the required activities. Given the need to determine the extent to which teachers applied their knowledge of MS under MSP, one could not ignore these problems. These teachers seemed to see these problems being part of the factors that tended to hinder progress in their efforts to apply MS under MSP. They also indicated that they saw some of these problems persisting even back in their schools, where they expected the situation to be even worse, thereby hindering their efforts to assist pupils in their learning of D&T. For the purpose of this study that was interesting to note, in view of the environment or conditions and realities under which teachers were going to work. Teachers were also afforded a chance to suggest possible solutions to specific problems and explain how exactly they planned to go around some of them. In their most popular suggestion, teachers wanted to see schools embarking on various fund-raising activities, especially those involving parents.



The *second cohort of interviews (**Cohort 2**)* were conducted just before the practical examination in MSP and soon afterwards. Before the examination, teachers were asked about: how well prepared they felt for the oncoming examination; the extent to which they anticipated MS to feature in the examination (anticipated relationship between MS and MSP), and the extent to which they anticipated their knowledge of MS to be useful/applicable during the examination.

On how well prepared they felt for the on-coming practical examination, all the 11 teachers who had volunteered to participate in these interviews confirmed being prepared. The only difference was in the level or degree of preparedness, where 5 were ‘very well prepared’; 4 were ‘well prepared’ and 2 were ‘fairly well prepared’. One of the reasons teachers gave for this reasonable level of preparedness was that they had studied MS, whose elements/concepts they anticipated comprising a major part of the examination. This also strengthened the argument that they were applying their knowledge of MS in several ways to solve practical problems under MSP. All the 11 teachers envisaged MS being visible or being reflected in the examination. They also supported their views by giving specific examples reflecting a lot of valid ideas. Most of what they said demonstrated appropriate understanding of the following concepts and facts: materials being arranged in particular groups in the periodic table; elements of similar electronic configuration being suitable replacements of each other in specific applications, and choosing specific materials for particular applications according to their characteristics or properties. These ideas appeared adequately relevant to justify and confirm the need to relate these two subjects; not only for the purpose of the oncoming examination in particular, but also to promote subject integration in general.



Soon after the examination, teachers were interviewed in order to determine their views then, as compared to those just before the examination. It was hoped this would give an idea of the teachers’ actual experiences regarding the application of MS during the examination. There was a need to find out whether or not the teachers had felt satisfied with their performance in the examination, found themselves well or adequately prepared for the examination, found their MSP and MS courses reflective of each other during the examination, and found their knowledge of MS useful and/or applicable.

From their responses during the interview, teachers clearly indicated that they were satisfied with their performance during the examination. This was very much in agreement with what they had implied before the examination when they overwhelmingly indicated that they felt adequately prepared for the examination. Teachers also confirmed having found the MS and MSP courses reflective of each other during the examination, where their knowledge of MS had proved useful.

Apart from interviews, more evidence of teachers applying their knowledge of MS in solving practical problems under MSP, immerged from records and accounts in their ***design folios***, obtained through ***content evaluation***. Teachers compiled these folios during the course of their practical activities under MSP. From the 36 design folios collected and evaluated, there was further evidence of teachers using their knowledge of MS in solving practical problems under MSP. Records in folios showed that the application of MS varied in intensity, depending on the focus in various sections. While there was more evidence of application in some sections (for example, in sections 6 and 7), there was much less in others (for example, sections 1 and 2).

Having achieved a global overview of the picture emerging from the design folios, one could sum up the general observations and declare that there was adequate and satisfactory evidence of teachers actively applying their knowledge of MS during MSP, despite differences in the intensity of that application within the various sections. All the bits and pieces of evidence resulting in the findings presented in this study mainly served to confirm and qualify most of the claims teachers made in questionnaires, especially in the Pre-&Post-Test Questionnaire (Questionnaire 'A2') and during interviews. Teachers claimed that they had found their learning of MS profitable in improving their knowledge and understanding of materials in terms of properties and applications. They also claimed having found their knowledge of materials applicable in solving D&T related problems during their various activities in MSP.



Another earlier observation/development confirmed by the results and findings here was the drastic shift in the perceptions of teachers where they initially exhibited perceptions that were opposed to most of the cardinal principles underpinning D&T and ended up in a complete turn around, resulting in more positive perceptions.

Developments where findings indicated teachers exhibiting low understandings on selected items or concepts to do with MS before the course in MS and ended up with much higher levels after the course were also proven and confirmed through findings from design folios. In fact, most activities leading to the compilation of these documents occurred during class and workshop observations, planned and conducted as described in Chapter 3. Teachers were observed engaging in various practical activities, including compilation of the said folios.

**Conclusions**

To conclude this study, it was necessary to make a review of the results and findings in relation to all the research questions, primary and secondary, taken from Chapter 1. Having departed from these questions, it was now time to come back and finish on the same note as dictated by these questions in view of the purpose of study. There was a need to take stock of what had transpired in terms of addressing and answering these questions. Therefore, given this background and in line with the associated results and findings, the following conclusions were arrived at:



**1**. It was important to consult and involve teachers at all levels in this study, from the design, development, production, implementation and evaluation of the instructional materials used for their professional development.

**2**. The perceptions of teachers became more positive towards D&T with more scientific knowledge, coupled with better understanding of the concept as an approach.

**3**. Teachers became more confident to teach about specific aspects/concepts of MS at ‘A’ Level with increased knowledge and understanding of those concepts.

**4**. Teachers found their knowledge of MS applicable in solving practical problems in MSP.

**5**. Subject integration is very important in the teaching and learning of D&T as was proven true in this study, where collaboration between MS and MSP was a fruitful experience.

**6**. All having been said and done up to this far, one can now perhaps confidently declare that the MS course at the core of this study was effective in promoting positive changes in the perceptions, understanding and knowledge of teachers regarding content in MS and instructional practice in D&T.

**7**. Another look at the conceptual/theoretical framework revealed more activities within the instructional design model than had been noted before.

## 5.2 DISCUSSION OF CONCLUSIONS AND THEIR IMPLICATIONS FOR TEACHER EDUCATION AND RELATED ISSUES



The conclusions drawn and outlined above had far reaching implications on specific issues relating to the purpose of this study. Of particular interest were the following: MS within D&T education; Learner involvement in relation to the effectiveness of instructional materials; D&T education in relation to the professional development of teachers, and Developmental research in relation to instructional design.

### *5.2.1 Implications for the relationship between MS and MSP within the context of D&T education*

Conclusions 3 and 4 were drawn from findings relating to the application of MS during the MSP course, where specific implications were noted in relation to D&T.

**The application of MS under MSP**

The application of Material Science (MS) in solving practical problems under the Machine Shop Practice (MSP) course helped teachers to consolidate their knowledge and understanding of specific concepts in MS. Considering the question of 'curriculum relevance', it is important to note that this also related to the application of knowledge in society, especially where radical reforms are expected. In this study, this was mainly so in view of the position and persuasion of prominent radicals in the likes of Holt (1964), Goodman (1970), Illich (1971) and McLaren (1995) who have openly expressed disdain towards established methods of schooling. They have even gone to the extent of expressing contempt for the very society within which schools exist. All this has been in the quest for relevance in the business of schooling; the lack of which has resulted in schools being viewed as prisons, teachers as prison guards where pupils have been the prisoners.

Conclusions 4 and 3 appear closely related in the sense that they both touch on aspects relating to 'theory' and 'practice'. However, these terms have been viewed from a highly relative perspective. While on the one hand, theoretical knowledge is applied to solve an academic problem (not necessarily 'practical' in the physical sense of practical application), on the other, theoretical knowledge is applied to solve practical/technical problems in the sense of practical workshop activities.



In this study, the whole issue was about applying theoretical and scientific knowledge, practically manipulating tools and materials to solve practical/technical D&T related problems, mainly through experimentation. That in itself helped to strengthen understanding by giving teachers an opportunity to prove scientific knowledge and principles either way (correct or wrong) through experimentation and observation to make sense out of the results in a given experiment. For example, most experiments were conducted during workshop activities where teachers were implementing their ideas as a way of fulfilling the requirements of the design process. Evidence of teachers applying their knowledge of MS during these practical activities (under MSP) could be located in their design folios, as already explained under the report of results and finding in Chapter 4 as well as in this chapter under Section 5.1.3, summarizing results and findings.

According to Mulberg (1993), if we agree that our main interest in teaching D&T is to inculcate knowledge, then there will obviously be implications that it is derived from procedural activities as propounded by Chalmers (1990), Medawar (1990) and Carey (1994). In this sense, knowledge is derived from distinct practical experiences. This suggests a very strong relationship between theory and practice. Even in this study, relating knowledge to experience helped to give teachers an opportunity to assess their levels of understanding by putting their theoretical knowledge into practice and by so doing, closing the gap usually existing between the two (theory and practice) as alleged by Roth, Lawless and Tobin (2000:1-15).

In his study of D&T teachers, Mulberg (1993) found that they (teachers in a particular group) all viewed the subject as more than a physical skill to be taught in the classroom. They also rejected a rigid definition of the subject, realizing that such a definition would exclude as much as it would include (Mulberg, 1993). In fact, they viewed D&T as not just involving the technical, but as a subject interwoven with the social, cultural, and political aspects within a given context. In many ways, this seems to be very much in agreement with Goodson's (1994) assertion that, '--- curriculum results from social activity where it is designed for both deliberate and emerging human purposes'. This is exactly what Meachum (2001) and Vygotsky (1986) have termed 'social constructivism', which in this study has also been accommodated within the instructional design model portrayed in Figure 2.2, thereby resulting in the whole study being developmental in orientation. In reality, social constructivism implies solutions to problems and/or answers to questions, not being pre-determined nor being standardized in any way. One could argue that, 'problem-solving' as a methodology in addressing problems (be they social, economic, practical, technical or otherwise), is based on principles founded upon constructivism. According to Hennessey and McCormick (1994), the appeal of 'problem-solving' as an approach for seeking solutions to problems lies in the fact that it is a natural activity where human beings have always faced problems, most of which they have tried to solve. For example, it is also a useful model for understanding technological development in that it can incorporate the broad range of variables involved in solutions to a variety of technological problems.



Coming to D&T activities, where teachers insist on progressive product development through set stages, in a so called 'D&T Process', students in fact adopt their own strategies in order to get the job done, but ritualistically use the teacher's approach to satisfy assessment demands (Hennessey & McCormick, 1994). This is a complete negation of what D&T stands for, from a constructivistic perspective and perhaps teachers should always be on the look out in order to check on this tendency. According to Williams (2002), constructivism as it underpins D&T, holds that pupils/students learn by constructing knowledge in their own ways, and the teaching of D&T is facilitated where the presentation of content is organized in these constructive ways. In their opposition to prescriptive models of curriculum and instruction, Akerman and Carlson (1991:102) maintain:

> The time is past when we could accept unequivocally the kind of science that has dominated educational research, including (curriculum) development, that has nurtured a belief in decontextualized precision for the sole purpose of management and control, --- leading to prescriptive models of curriculum and instruction, uniform methods of teaching and testing, and outcomes of learning that can be standardized and measured. --- This has resulted in non-expressive and non-emotional forms of education; education that is value neutral and technical and that neglects the human spirit.

Lessons have also been drawn from Conway (1992) who has identified one of the aims D&T education as to give opportunities for the young people themselves to be creative and cooperative, in a process that develops sensitivity to other people's needs and cultures. On a similar note, the 2002 version of the 'A' Level D&T syllabus has enshrined several tenets, among which there is one where learners are expected to work in groups, thereby collaborating in the business of learning. From a social constructivistic orientation, this is where reputable proponents like Fantini (1986), Shane (1981) and Toffler (1983) have proposed a curriculum that emphasizes cultural pluralism, equality and futurism whereby pupils/students are taught to appreciate life in a world of many diverse nations. In this case, designs are meant to accommodate variety and diversity. Clearly, most of the tenets associated with 'social constructivism' are very much opposed to those associated with the individualistic tendencies of 'capitalist schooling' which McLaren (1995) describes as being generally perverse in that it strives through its curriculum to create a culture of desire, going against communal consensus and hiding from pupils and the general public the gaps in society, inequalities therein and the intolerance of differences. Mclaren (1995) further suggests that capitalist schooling presents an illusion of harmony. He is however quick to admit that, on the other hand, the contemporary schooling he is advocating for dares students to become productive, loyal citizens which in a way subjects them to total obedience of normative codes of conduct and standardized regimes of values and valuing. There are also some social constructivists who have been influenced by reconceptualists like Apple (1986), whose work has been so radical that he has been labelled, 'neo-Marxist'. These scholars have highlighted and articulated the relationship between what they perceive to be political, economic and cultural domination of the individual in relation to schools and society. For the benefit of this study, all these diverse and opposing views were examined in order to have a balanced path accommodating such controversial issues and perspectives in debate.

Given the sense behind the fourth conclusion, it is perhaps important to note that practical problems come in a variety of descriptions and are always relative where individual nations are expected to continue promoting their own cultures, values, and political and/or economic systems although in a universal curriculum pupils/students are expected to learn a common core of knowledge and skills essential for global peace and cooperation as propounded and advocated by Boulding (1985) and Garter (1987). Under such an international curriculum, pupils/students need to acquire an awareness of global events and tools for understanding 'world-wide systems' which are; social, political, economic, physical, biological, communicative, and evaluative. A critical examination of these systems will show their relationship with most of the tenets enshrined in the philosophy of D&T. Curriculum specialists who believe in the approach Dewey (1938) has termed the 'Humanistic' tend to place faith in cooperative learning, independent learning, small group learning and social activities, as opposed to competitive teacher dominated learning only based on cognitive instruction. Each learner, according to this approach, has considerable input or contribution into the curriculum and shares responsibility with teachers and curriculum specialists in planning classroom instruction (Ornstein & Levine, 1991). This was one of the principles adopted in this study where serving teachers played an active role in the design and development of the materials meant for their professional development. However, this is not to deny the controversy surrounding the humanistic approach where it has continued to face criticism from those who argue for what they perceive to be higher standards. These critics assume that to be successful in the life to come, learners require a good base in the academic core subjects and they believe that the future requires ‘thinkers’ and not ‘feelers’ (Eisner, 1994).

From yet another critical perspective, Slattery (1995) posits that the benefits of a theory in any field should be to provide a framework to conceptualise and clarify important problems and techniques. He however laments; “--- curriculum theories that are correct and complete to serve as --- a basis for practical decisions do not exist”. He also argues that educators, including curricularists, tend to embrace ‘theory as an ideology’, even though much of what they say is suspect and closes us to other aspects of reality and other values.

Sentiments by Slattery (1995) are also shared and reinforced by Ornstein and Hunkins (1989) when they argue that most curriculum texts (especially instructional materials) are more theoretical than practical. They (Ornstein & Hunkins, 1989) also suggest that despite their claims, curricularists seem unable to make the leap from theory to practice, from the textbook and college course to the classroom and school (or any other organization that might be the work-place). Most of these observations are also summarized by Osterman (1990), Schon (1987) and Schon (1989) when they complain that good theory, in curriculum and in other fields of education, often gets lost as practitioners (say teachers) try to apply what they learned in colleges to the job setting in a search for practical solutions to common, everyday problems. To reinforce this point, Osterman (1990) proceeds to argue that, the problem of translating theory into practice is further aggravated by practitioners who feel that practical considerations are more important or worthwhile than theory. For example, there are many teachers and school heads in Zimbabwe who view theory as unpractical and ‘how to do’ approaches to teaching and learning as more helpful. In most cases, there appears to be confusion whereby many theoreticians ignore and look down upon practitioners and vice versa, in a vicious circle. Moreover, many theoretical discussions of curriculum are divorced from practical applications in classrooms, and many practical discussions of curriculum rarely consider theoretical relationships (Ornstein & Hunkins, 1989).

According to Ornstein and Hunkins (1989), practice involves selecting strategies and rules that apply to various situations since these are not always the same. This becomes especially evident when practitioners try to apply the theories they learn in their textbooks. In this case, adopting the right method for the appropriate situation is not an easy task and involves a good deal of common sense and experience (Ornstein & Hunkins, 1989). This is something one cannot learn from theoretical discussions. No matter how scientific we think our theories are, a certain amount of art is involved in the practice of curriculum; intuitive judgements and hunches that cannot be easily predicted or generalized from one situation to another, and this confounds theory (Ornstein & Hunkins, 1993). 'Just what then does curriculum practice involve?' one might ask. According to Ornstein and Hunkins (1988), the response is open to debate. But this is where one might suggest that curriculum practice includes understanding the constraints and specifics operating within the school (or any other organization in which one might be working) and comprehending the goals and priorities of the school and the academic needs of the students and staff. It also involves planning and working with procedures and processes that can be implemented in classrooms (or any other formal group settings) in a school or any other formal institution (Osterman, 1990). A successful practitioner in curriculum is capable of developing, implementing, and evaluating the curriculum (McWilliam & Taylor, 1998). In addition, s/he can select and organize (1) goals and objectives; (2) subject matter; (3) methods, materials, and media; (4) learning experiences and activities that are suitable for learners and then (5) assess these processes (Ornstein & Hunkins, 1989).

In the final analysis, it is up to the curriculum specialist to recognize that the theoretician and practitioner have different agendas and perceptions of what is important (Ornstein & Hunkins, 2004). This assertion appears to be based on the belief and premise that the practitioner does not function as the mere user of the theoretician's or researcher's product and the theoretician is often interested in knowledge that might have little or no value to the practitioner. One role for the curriculum specialist, whom some educators usually call the 'reflective practitioner,' is to generate dialogue between the theoretician and practitioner in order to establish modes of collaboration that can benefit both groups (Ornstein & Hunkins, 2004).

Most of the views and perspectives mooted and shared here could perhaps best be used to inform discussions and even programme designs in teachers' colleges for the benefit of trainee teachers at various levels in the search for the best way to relate theory and practice in teaching and learning, with specific reference to D&T Education.

### *5.2.2 Implications for learner involvement in relation to the effectiveness of instructional materials*

Implications are in this case drawn from Conclusion 1, which resulted from the active participation of teachers in the design, development, production, implementation and evaluation of the instructional materials used in this study.

**The importance of teacher participation in the production of the instructional materials designed for their professional development**.



The involvement of teachers was in this case, a fruitful move. Their close consultation during preparatory investigations resulted in their views, opinions and suggestions being a great contribution towards the required instructional materials. For example, even the identification of the topics that were eventually included in the Material Science (MS) course outline and the choice of the associated instructional technology resulted from such consultations. Wheeler, Chuaratanaphong, Bhumirat, Eamsukkawat, Pumsa-ard, Shinatrakool, Sirigirirakal and Sookpokakit (1992), confirm the importance of such consultations and maintain that the involvement and participation of teachers in the production, testing, and evaluation of new, locally based instructional materials may not only lead to the use of appropriate materials; it may also have a significant effect on the professional development of the teachers so involved.

The relevant conclusion here (Conclusion 1) is very much in agreement with Southwood's (2002) findings in a study she called 'a journey of negotiation' involving teachers in a four year study specifically focussed on the development of a collaborative approach to the professional development of teachers. As was the case in this study, with D&T teachers, the approach followed by Southwood (2002) recognised and celebrated teachers themselves as resources for their own professional development. In this study, the idea of actively involving teachers in their professional development as equal partners sharing responsibilities with the researcher, in terms of decision making, was also reinforced by the inclusion and development of resource persons from among the concerned teachers. As explained in Chapter 3, these resource persons actively participated in the teaching of their colleagues in a latter intake to a B.Ed degree program.

An off-shoot of this study, being a book chapter in press, clearly describes the process covered during the preparatory stages of this study as an innovative move 'towards a model for course development with specific reference to MS for D&T teachers in Zimbabwe (Kwaira, Kolsto, Meerkotter & Ogunniyi, 2006). One outstanding characteristic or feature of this model, regarding teacher education and training as applied in this study was that it did put the learner (serving teacher) into the centre where s/he became highly involved as part and parcel of the whole developmental process of the course; from the plan, design, pilot phase, implementation and, right up to the evaluation phase.



The active participation by serving teachers in the design and development of their study materials is not really a new phenomenon. For example, Ornstein and Hunkins (1998) chronicle events of the 1960s when students started to take control and play a more active role in their education. This was a spin off from student movements perceiving the subject-centred curriculum as irrelevant to the prevailing social times of that era. Students demanded a more progressive student centred curriculum. Observations by Ornstein and Hunkins (1998) were actually rooted in earlier assertions by Mahai and Masisi (1982), maintaining that participatory research was an approach taken by both the respondent and the researcher collectively, in a harmonious manner to solving specific common problems facing the two. In this study, such an approach to research was based on social justice and equality with a lot of ideological implications. Many of those who believe in this approach (non-alienating, non-dominating and anti-oppressive as it is), do so because of a conviction based on the principles associated with it (Gardner, 1990, Eisner, 1991a.

Eisner, 1991b. & Eisner, 1992). According to some ideologists from the socialist camp, this approach is highly recommended in societies where group interaction is supposed to be open and emancipatory in nature (Mahai & Masisi, 1982; Bloom, 1995).

In this study, getting teachers to actively participate as learners was another move motivated by a strong faith in constructivism. From a constructivist stand point, each learner must participate in generating meaning. For example, according to Hunkins (1995) and Martin (1997), such learning can only exist in situations where the new learning is constantly being connected or related to existing knowledge and skills, that is, prior experiences. Learning is optimized if the learner is aware of the learning processes s/he is employing. It is this awareness of one's cognitive processes and associated principles that Hunkins (1995) defines as 'meta-cognition'. According to this phenomenon and going by the constructivist persuasion, the learner becomes cognizant of the procedures and principles employed in the creation and application of knowledge in a given context. This, in itself, calls for creativity and critical thinking as propounded by Sternberg (1986).



As a constructivist, influenced by the likes of Sternberg (1990a.) and Brooks and Brooks (1993), I designed this study with the belief that the task for learners is not to passively accept information by mimicking the wording or conclusions of other people, but rather to engage themselves in internalizing and reshaping or transforming information via active consideration. Being important sources of information on their perceived professional problems and needs, I believed teachers were the right people to consult in this regard. However, their responses had to be balanced with my own interpretation of the demands in the new D&T syllabus/curriculum. The guiding principle was the issue of relevance, as taken from literature. For Jurgen Habermas, knowledge becomes more relevant with more practical application, relating theory to practice (Holub, 1991). The teachers in this study also provided reliable information on what they anticipated to be logistical problems and difficulties in the teaching and learning of D&T at 'A' Level. This was very important for planning purposes before implementation of the program (MS course). The decision to actively involve teachers at various levels was also based on the assumption that since in-service programmes must reach their intended audiences, they should be accessibly scheduled for implementation. This decision was strengthened by lessons from Joyce and Showers (1988); proposing and encouraging open discussions on any new programmes throughout the implementation process. Their justification for such discussions is based on the belief that they allow implementers of new programmes to voice their objections or concerns and consequently reduce opposition and/or resistance by the intended users. Effectively and according to the principles of developmental research, in-service programme designers must also evaluate the situation and determine whether they are achieving their objectives and whether they are in harmony with the underlying philosophy of the concerned school system (Joyce & Showers, 1988).

It should however be underscored that, 'developmental research' places high demands on the course designer, where after developing the instructional materials, s/he proceeds to evaluate the whole instructional program. Consequently, the same individual has to expect both positive and negative results from the evaluations and take them seriously for the sake of improving and developing the tentative materials further, without making biased interpretations in subsequent cycles. This way, the quality of the end product improves through constructive messages from formative evaluations, taken seriously (Ally, 1997).



In this study, the involvement of teachers in the design, implementation and evaluation of the instructional materials also helped to strengthen their sense of ownership of the materials. By indicating their views and opinions on the materials, they had an opportunity to make an input in their design and development. This appears to have promoted their sense of responsibility regarding their professional growth. There was adequate evidence of this approach also making the instructional materials relevant to the professional needs of the concerned teachers, as users (Kwaira, Kolsto, Meerkotter & Ogunniyi, 2006).

The outlook of events here seems to suggest the importance of teacher educators/trainers actively engaging trainees at various levels of course design and development, especially by accommodating their views and ideas through properly planned course evaluation strategies, say at the end of every semester or some other suitable time. After evaluation, new ideas would then be carried over to another round of planning in preparation for a new round of curriculum implementation (Doll, 1996). According to Mahai and Masisi (1982) and Hunkins (1980), participatory planning is a process of mutual agreement and learning, where the problem or problems and its/their solution(s) is/are participatorily identified and planned. In such a process, the expert/consultant and his/her client are cooperating on an equal basis (Sarason, 1981; Sarason, 1990). Evidently, after such a rigorous process of planning and development, implementation is likely to be successful. Miles and Louis (1990:57) confirm that successful implementation of curricula results from careful planning and they qualify their argument as follows; "--- planning processes address needs and resources requisite for carrying out intended actions. It involves establishing and determining how to administer policy that will govern the planned actions". They further note that for meaningful planning, there must be vision building. Miles and Louis (1990) prove this through experience from research where they found that those schools successfully implementing change and improving their programmes had staff passionately holding similar images of what the school needed to become. The teachers they studied were committed to the new programmes and had developed enthusiasm about the innovation. Implementation of the new programme afforded teachers, together with theirs schools, an opportunity to make the vision a reality (Miles and Louis, 1990:57-61). Both parties shared responsibility in seeing to it that the programme was successful, regarding the outcome of implementation. Effectively and by implication, this seems to suggest the fact that, just like is expected of the teacher, the school has to be innovative, as a matter of policy and for the sake of progress. According to Ornstein and Levine (1990), if the school is innovative or reform orientated, then changes are expected and the school tends to create and sustain a culture for change. From the outset of curriculum development, the ideal would then be for curriculum leaders to furnish those involved, with occasions and opportunities to develop such attitudes, as would promote a sense of ownership and belonging to given programmes/schemes. This observation has implications on the nature of preparation teachers must receive during their stint in colleges and departments of education in universities. The model underpinning this study was a good example, demonstrating such an experience rooted in Taba's (1962) and Curle's (1970) arguments of teachers being the main actors in most school education.

Since according to Curle (1970), teacher education is the main-stay of any education system, it is perhaps logical to also conclude that for much to be achieved through curriculum change and innovation, the human factor (the teacher) should be appropriately accommodated within the system. Of late, Fullan (1991) has come out in full support of Taba's (1962) and Curle's (1970) positions regarding the place of the teacher in school programmes. In most of his recent works, Fullan has established that most education systems fail to achieve their targets, in terms of change and innovation mainly because those in charge ignore the 'teacher factor' while spending time and money modifying only the programme or process, especially in universities. These observations by Fullan (1991) are confirmed by Ornstein and Hunkins (2004), alleging that in most cases, such authorities concentrate most of their energies on changing the programme but pay scant attention on the needs of teachers; especially professional ones.

According to Sarason (1988), the curriculum/programme designer should facilitate the active participation and involvement of teachers in order to allow for experiential learning in an environment that promotes openness and trust. Sarason's (1988) ideas are reinforced by Harvey (1990), who maintains that teachers also need time to 'understand' before 'trying' new programme and to 'reflect' on new goals and objectives in relation to the mission of the school. Given time, teachers would be in a better position to make sense out of the new curriculum contents and the expected learning experiences (Harvey, 1990). All these are the kinds of suggestions, ideas and warnings that this study took advantage of from the beginning. In a situation such as ours in Zimbabwe that is currently turbulent, given the harsh and hostile economic conditions, this congruence is especially important. The assumption is that, the more change is related/linked to the central mission of the school or education system, the more likely is its survival in the face of shifting, but less central priorities! On a similar note regarding teaching, we can not expect teachers in practice to have developed a full understanding of new subjects and new approaches without an appropriate orientation since in most cases their views are necessarily based on their current understanding (Kwaira, Kolsto, Meerkotter and

Ogunniyi, 2006). In terms of lessons from this study, regarding teaching approaches, it appears course developers in colleges and universities need to consider both the students' views and recommendations from literature, mainly to ensure the use of exemplary and active learning.

### *5.2.3 Implications for D&T education in relation the professional development of teachers*

Implications were in this case drawn from conclusions 2, 3, 5 and 6, where the focus was on: change in the perceptions of teachers towards D&T, confidence of teachers regarding teaching MS at 'A' Level, the importance of subject integration and the effect of the MS course on the professional development of teachers.

**More positive perceptions towards D&T after the MS and MSP courses**

At entry point into the Bachelor of Education (B.Ed) degree programme, teachers exhibited perceptions that were typically against the idea of D&T. This was clearly reflected in their responses to Questionnaire 'A2' at pre-test level. In most of their responses, the general picture showed that they were completely opposed to most of the cardinal principles underlying D&T as an approach. On further investigation, these perceptions were found to be attributed to the initial teacher education and training those teachers had received in teachers' colleges. Most of the perceptions teachers brought into the programme were relics of their initial orientation from teachers' colleges, where history shows technical subjects being taught through the traditional approach. Under such an approach, teachers become accustomed to the habit of providing pupils with solutions to problem, instead of confronting them with challenges that promote meaningful learning. Obviously, for teachers to continue thinking in the traditional mode after the advent of the D&T approach is a negation of the progressive efforts aimed at rejuvenating technical education in Zimbabwe (Kwaira, 2000).

If D&T is about the application of scientific knowledge to create systems that help to solve the problems of human adaptation in particular environmental spaces, then the understanding of those systems most likely requires some scientific knowledge and principles (Bybee & Landes, 1988). And, the development of such scientific understandings is clearly the task of Science and Technology Education under the auspices of the broad goals of D&T (Marker, 1992). All this has implications for teacher education and training, and for this kind of knowledge to be promoted in schools, teachers must be equipped with the relevant and appropriate knowledge and skills (Hichman, Patrick, & Bybee, 1987; Giese, Parisi, & Bybee, 1991). However, knowledge and skills on their own have not been the absolute ideal in most cases. According to Marker and Mehlinger (1991), the starting point is a positive mind-set, characterized by positive perceptions.

The negative attitudes towards D&T that teachers started off with were not really an isolated case in the field of teaching and learning. Several studies have had similar findings regarding perception towards particular phenomena in given contexts. For example, Ingram (1994) discovered that teachers, especially the newly trained, had a tendency to teach as they were taught. As already observed, the teachers who were involved in this study had been taught through the traditional approach during their initial teacher training. It was therefore, not surprising to see them sticking to the same methods long after their training. And, to break out of this vicious 'cycle of sameness', Ingram (1994) recommends 'teacher education' as a tool. However, she maintains that, to do so, leaders in education should provide a dramatic intervention during teacher preparation in order to change minds as well as impart new knowledge and skills. Thus teacher education is: the catalyst for change, the means of initiating a process wherein D&T-augmented teaching will infuse all aspects of formal education across all levels (from primary to tertiary) resulting in students learning more, learning better, and doing it (learning) faster at cheaper and a steadily declining cost (Ingram, 1994). In this case, the argument is; 'If teacher education is the missing link, then the missing ingredient is a D&T literate cadre of college and university teacher educators. By implication and according to this position, the starting point should be the teacher educator who should be appropriately qualified in order to prepare student teachers for their roles in schools.

One other observation in this study was that, despite having a lot of D&T related items in the Woodwork and Metalwork 'O' Level syllabi, implying a lot of D&T related activities going on in schools, the teachers involved in this study still appeared not quite familiar with D&T as an approach and as a subject. This explains why they were initially very much opposed to most of the important principles of D&T. What one could not easily understand however, was the actual reason why teachers had not had some kind of orientation from the syllabi they were already using in schools in order to grasp some of the cardinal principles of D&T! The assumption was that since these teachers had been using syllabi deliberately designed to promote the D&T approach, they were going to be familiar with some of the cardinal principles therein. This is what was absent in their initial perceptions. One could not help wondering how this could be, when according to the Learner Analysis Questionnaire (Questionnaire 'A'); some of them had claimed to be familiar with the topic on 'the theory of D&T'! One could then not help suspecting a situation where teachers were simply singing the rhetoric choruses of D&T in schools, without necessarily having the grasp of the relevant concepts involved. Therefore, to get an explanation to this phenomenon, I referred to Rich (1988), who encountered a similar situation. During a reform initiative, teachers did not perceive issues as expected and on investigation, Rich (1988) discovered that among several reasons, one of the most outstanding was that teachers were in reality, resisting the change while at the same time pretending to support it.

Drawing parallels with the situation encountered in Rich's (1988) study, it appears the design and related classroom practices in the current national curriculum in Zimbabwe, have proved persistent over time and have become very resistant to change. The practices, especially those associated with traditional approaches, have basically been maintained; thereby persisting throughout our history of education. This has been the situation, despite being improved by some fundamental changes and important advances, particularly soon after independence (Jaji & Hodzi, 1992). Traditional approaches have been deeply rooted. They are now resistant to alternatives widely supported, and acknowledged by many as the 'best way' to run schooling in technical education. In a similar situation, Klein, (1980) declares that there are powerful forces and groups, both within and without the field of education, helping to maintain the status quo of the subject matter curriculum design and its related classroom practices. Some of these include accountability for education, the types of educational materials produced, current teacher education programmes, societal and parental expectations about what schools should do and what an educated person is like, the metaphor used for shaping, describing and studying schools, and a very prestigious research base (Klein, 1985). From Klein's observations it became worthwhile to find out how the issue of accountability could be placed within the Zimbabwean situation in order to explain the above scenario, regarding the context of the negative initial perception on D&T.

In Zimbabwe, the push for accountability in school education has largely been in the form of holding teachers responsible for pupil/student achievement. According to Klein (1986), the teacher is the primary instrument/vehicle by which students are expected to learn. This view implies that, what a teacher does in the classroom must produce student achievement as measured primarily by standardized tests, which constitute a major aspect of the subject matter design. Klein (1986) asserts that due to this push, teachers feel compelled to engage in those practices which are clearly linked with student achievement and largely ignore practices which do not correlate with higher test scores. This way, they become accountable to the lay communities (Klein, 1985). In this country (Zimbabwe), we have seen schools and teachers whose pupils/students have obtained high test scores being publicly recognized and rewarded, regardless of the type of community in which the school is situated or the level of funding and resources available to support teaching and learning. Thus, teacher accountability for pupil/student learning with the corresponding proof of objectives and standardized results has probably been one major factor in maintaining the entrenchment of the subject matter design (Jaji & Hodzi, 1992).



Klein (1994) also reports on teachers relying heavily on commercial materials created specifically for classroom application. These materials, especially textbooks and related materials clearly reflect a subject matter design and its related classroom practices. The curriculum usually presented in most commercial materials logically organizes subject matter for students to learn, relies heavily on more passive activities by which students learn while the teacher maintains order and control in the classroom and uses some form of achievement testing as the major vehicle for determining student learning.

Foshay (1980) argues that pre-service teacher education is also a major contributor to maintaining the status quo in curriculum design and practice. Given the Zimbabwean context, as detailed in this report, history has appeared to have repeated itself. A lot of what Foshay observes way back in the early 1980s' still appears commonplace in most of our schools today. Teachers in various programmes seem to have been educated to believe that the curriculum is something handed to them and they are expected to strictly teach from it, taking it as it is.

Considering all the issues raised and highlighted here and the circumstances surrounding them, one can now see and understand why teachers came into this study with such a traditional orientation. Indications were that, there was a lot of learning required if there was going to be any shift in orientation for anything better and more positive or progressive. This is exactly what transpired in this study, resulting in the positive perceptions that we ended up with as claimed under the relevant conclusion in this case.



From the turn of events in this study regarding developments where teachers ended up exhibiting more positive perceptions towards D&T, after MS and even more so after MSP, one can hardly deny the fact that this program was a successful intervention. This development is perhaps attributed to a situation where teachers gained knowledge and understanding that helped them to see the concept of D&T from new light. It is perhaps this kind of intervention that we should also have even at initial teacher education/training levels.

**Teachers becoming more confident to teach some aspects of MS at 'A' Level**

According to the third conclusion (Conclusion 3), teachers became more confident to teach about specific aspects/concepts of MS at 'A' Level with the increase in knowledge and understanding of those concepts. What this seems to imply is the fact that, in order to teach confidently, one must be well prepared in terms of knowledge and understanding of the materials to be taught. According to the findings in this study at pre-test level, teachers expressed and exhibited very low levels of confidence in the event of teaching the various aspects of MS at ‘A’ Level. However, after the course in MS they became far more confident. Prospects were even brighter after MSP. It appears all these developments served to prove the point that one can only be confident to teach about what s/he knows and understands. Before teachers learn about, and understand MS, chances are very slim that they would be confident enough to teach the subject, especially at ‘A’ Level, given the demands in terms of depth. This explains why teachers exhibited very low confidence at the pre-test level of Questionnaire ‘A2’, only to show a drastic improvement after the course as reflected at post-test levels. Given this background, it is necessary for one to have an idea of the implications of this development on teacher education/training, in view of the current situation in Zimbabwe, regarding the teaching and learning of technical subjects with specific reference to D&T.

According to Pinar, Reynolds, Slattery, and Taubman (1995), any field of study basically involves theoretical and practical knowledge. ‘Theory’, in this case implies advanced and valid knowledge available that can be generalized and applied to many situations. ‘Theory’ often establishes the framework of the field and helps practitioners within a given field to analyze and synthesize data, organize concepts and principles, suggest new ideas and relations, and even speculate about the future (Beauchamp, 1981). Beauchamp also proceeds to define ‘theory’ as the knowledge and statements that “--- give functional meaning to a series of events and take the form of definitions, operational constructs, assumptions, postulates, hypotheses, generalizations, laws or theorems. This definition suggests a scientific and technical approach that emphasizes the domain of knowledge (Ornstein, 1987 & Ornstein, 1993). As was the case in this study, this is exactly why there was a need to have the teaching of technical subjects being scientifically orientated by the inclusion of an area like MS where materials are handled and explained scientifically.

Good theory in curriculum, or in education for that matter, describes and explains the various relationships that exist in a particular field (Short, 1987). It also implies that there is an element of predictability, or that there are rigorous laws that yield high probability and control. Good theory should also prescribe actions to be taken where the situation calls for action (Reynolds, 1990). A typical example in MS under D&T could be a case where one might need to take action in terms of solving a practical problem by making informed choices on materials and mechanisms for particular applications.

All the details outlined here, on the issue of knowledge in various fields, comprise what teachers must learn during their education/training in colleges and universities. Leaving college or university with this kind of orientation, teachers are likely to be so highly motivated that they teach their specific areas of specialization with adequate confidence. It works, as was proven in this study. Although teachers began at their lowest ebb, in terms of confidence to teach about aspects of MS at 'A' Level, they ended up being highly confident after the MS course. Considering the amount of consultation that went into the whole process, one can understand this, given all the activities that were involved. The findings contributing to the relevant conclusion (Conclusion 3) helped to prove the point that once teachers feel well prepared in terms of knowledge; they are likely to go into schools from a position of strength, regarding confidence. What also came out clearly was the fact that teachers needed to be given relevant and appropriate knowledge in view of their academic and/or professional needs. The effectiveness of such a move is actually confirmed by Cannon's (1983:28) findings in Australia where he concluded that, "---the successful practice of professional development in universities in the future will depend on the development of an adequate theoretical basis to inform practice".



**The importance of subject integration in the teaching and learning of D&T**

If subject integration could be said to be so important in the teaching and leaning of D&T, as was declared in this study, one would perhaps be interested in what it really means in the professional development of teachers. Teachers have been confirmed to be the nerve-centre of what happens in schools in terms of teaching and learning in particular, and/or curriculum implementation in general (Zimpher, 1974; Cobb, Wood & Yackel, 1990). And, if this is the case, it is then logical to consider teachers' colleges and departments of education in universities, epicentres of what happens to teachers in terms of their professional development. According to Cheney (1989) and the Holmes Group (1986), the way teachers are educated has a bearing on the way they later operate as professionals in their own right within schools. In this study 'subject integration' has already been established and confirmed as one of the cardinal principles in D&T. It is therefore among the several principles that must be promoted in curricula designed for the professional development of teachers in colleges and/or universities.

The assumption was that, if teachers were to get it right in their orientation during teacher education and training regarding subject integration, they were likely to get it right in their teaching, in relation to the same issue. Pupils/students would in turn get it right in their orientation as learners. This explains why Zimpher (1974), in her discussion of 'theory into practice' in teacher education, poses questions like: What should be the goals of the education of teacher educators? How should teacher educators be educated? What should constitute the curriculum for teacher educators?, and How can the education of teacher educators be evaluated? All these questions seem to be clearly pointing to one general direction; the issue of transmission and/or persistence, where whatever goes into the teacher/lecturer in terms of knowledge is expected to be passed onto the pupil/student in one way or another! Of course, this does not mean pupils/students (learners) taking everything in without question. Discussing the issue of 'theory into practice' Reagan (1990) asserts that professional knowledge/skills and mastery of the subject matter to be taught are central traits of teacher competence. Given this background, it should perhaps also follow that, the success of subject integration in schools depends on the way teachers handle it in their teaching, especially the extent to which they get flexible and accommodative in their approach, teaching at various levels. This relates to the issue of methodology, since it all depends on the way they teach, assess, and evaluate their subject areas (Bennett, 1984; Boyer, 1987).



The main advantage of subject integration appears to be in the fact that both teachers and pupils/students are able to share ideas, experiences and even expertise during problem solving activities. For example, Fraley and Vargas (1975) site a situation where responsibility for instruction was expected to pass from academic content experts to experts in the technology of instruction. In Zimbabwean institutions, where this might not have been going on, the issue might call for substantial changes in organizational structure, especially in higher education and particularly in teachers' colleges. There are many general approaches to change within organizations, among which Fraley and Vargas (1975) outline; organizational goals, motivation of individuals within the organization, staff (by replacing individuals), and the structure of the organization. This argument seems to be suggesting that 'instructional systems and organizations' operate more efficiently when run by diverse experts and technical specialists. This is exactly why; even in this study the approach from the beginning was to establish a scheme of integration between MS and MSP. This decision was influenced by authorities like Fraley and Vargas (1975), Zuga (1991) and Hammer and Thode, (1989). For example, Fraley and Vargas (1975) actually came up with a model of 'instructional systems organization' specifically concentrating on the issue of subject integration.

**The effectiveness of the MS course at the core of this study**

Conclusion 6 is clearly a decisive declaration confirming the effectiveness of the MS course, which was the central issue in this study. Considering the positive changes in the perceptions, understanding and knowledge of teachers regarding content in MS and instructional practice in D&T this was essentially an indication of a lot of learning having occurred. The course appears to have really made a difference in the professional development of teachers and was therefore very useful as evidenced by the positive changes in the perceptions, understanding and knowledge of teachers, going by the results and findings from the pre- and post-test runs of Questionnaire 'A2'. The question is then, 'What does this imply in the professional development of technical subject teachers in Zimbabwe?



According to Sewart (1987), instructional organizations should reflect the process of instruction in their structures where for example, academic instructional arrangements must be consolidated into large technological organizations placing the control of instruction under instructional technologists. In this case, an instructional system specifies teaching procedures so that there is a way of accounting for all behaviour; of both, learners and teachers (human or machine). These ideas are among those that were adopted for the development of the package of instructional materials used in this study; for example the specification of instructional strategies and/or teaching procedures.

According to Butt and Gordon, (1985), the ideal in this situation is to have the system(s) being designed to teach different content materials, to different target populations. In this study, the content comprised of various elements of MS and the target population or sample comprised of teachers of technical subjects.

The teaching procedures adopted in the model that was followed in this study were the ones also used in the crash programme of training for the development of the resource persons who participated in the teaching of the course. The active participation of teachers in the teaching of their colleagues was quite a success since the resource persons commanded a reasonable level of respect in their teaching activities. This situation was a lot more encouraging than the one reported by Baynes, Langdon and Myers (1977) at South Kensington College of Education (Later called the Royal College of Art) in the United Kingdom where a similar model involved the enrolment of craftsmen (designers) who were coming from industry trying to join the teaching profession. This programme eventually failed as a result of several criticisms; chief among which was the college being accused of training teachers to train teachers. The main fear was that the college was going to limit activities to low-level training. The college was eventually closed. In contrast, the model used in this study got a much better reception to be considered a success story after a somewhat reasonably good start.



### *5.2.4 Implications for developmental research in relation to instructional design*

In this section, the seventh conclusion (Conclusion 7) had important implications on the Instructional design model in line with the conceptual framework that guided events in this study.

**New revelations from another view of the instructional design model**

Events during the course of this study, revealed more activities than had been noted before within the model in Figures 2.2. By implication, experiences during this project seem to have resulted in more revelations. Although there have been several levels at which this model has been considered after adoption from Ally's (1997) original version in Figure 1.1, in subsequent figures (including 5.1 and 5.2), we are not really dealing with several models. From Figure 2.2, this is just one model that has been modified and developed or adjusted in order to serve the purpose in this study. The various figures are simply different versions of the same model, where Figure 2.2 was the main guide of the present study. This version was adopted after realizing the gaps and missing links in Figure 1.1 as observed and explained in Chapter 2. Given the task in this study, it was found necessary to adopt a more appropriate version through further modifications, resulting in Figure 2.2. However, during the course of this study, being developmental and constructivistic in nature, new horizons continued to emerge, unabated. This justified a review of the model. Therefore, it has been found necessary to look back and share more about these insights in order to inform further research.

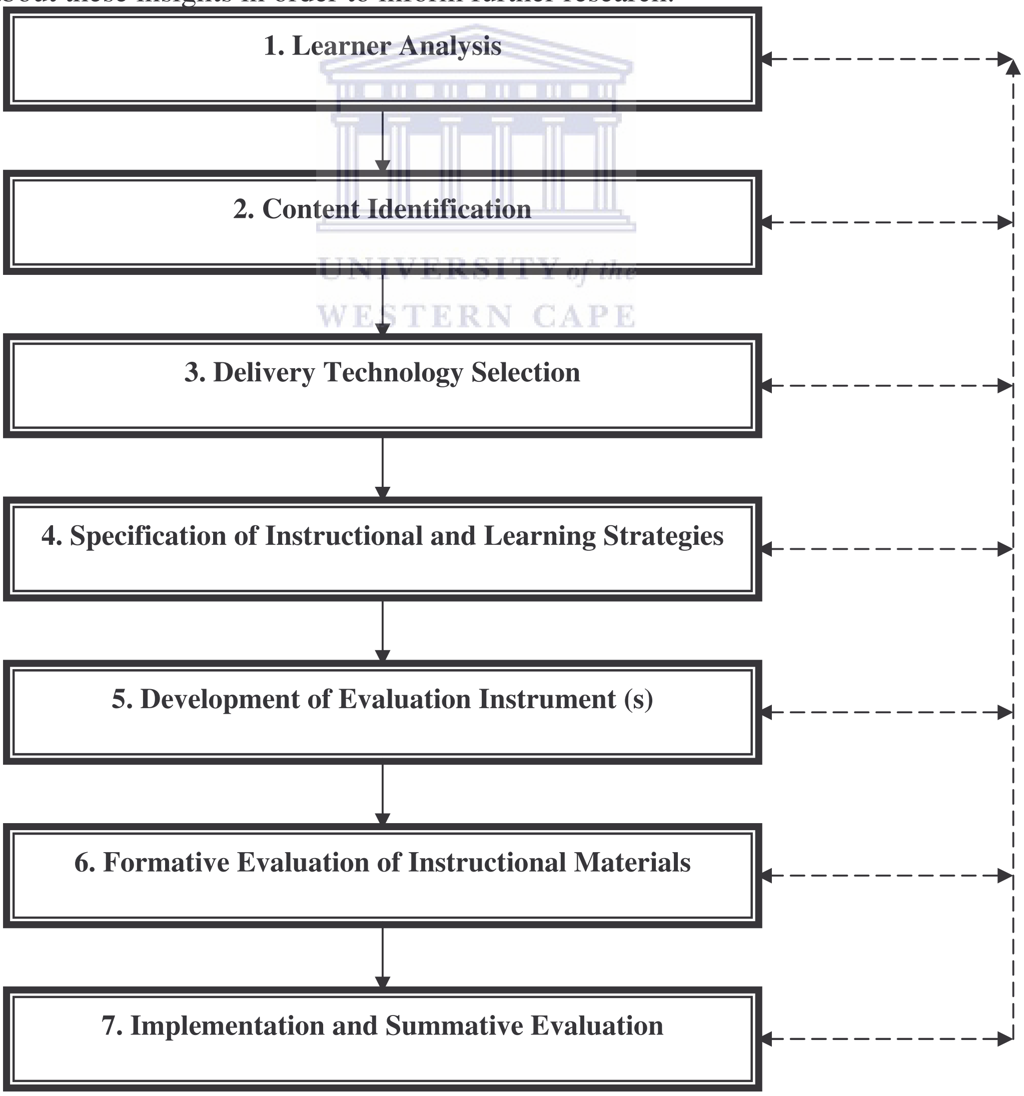
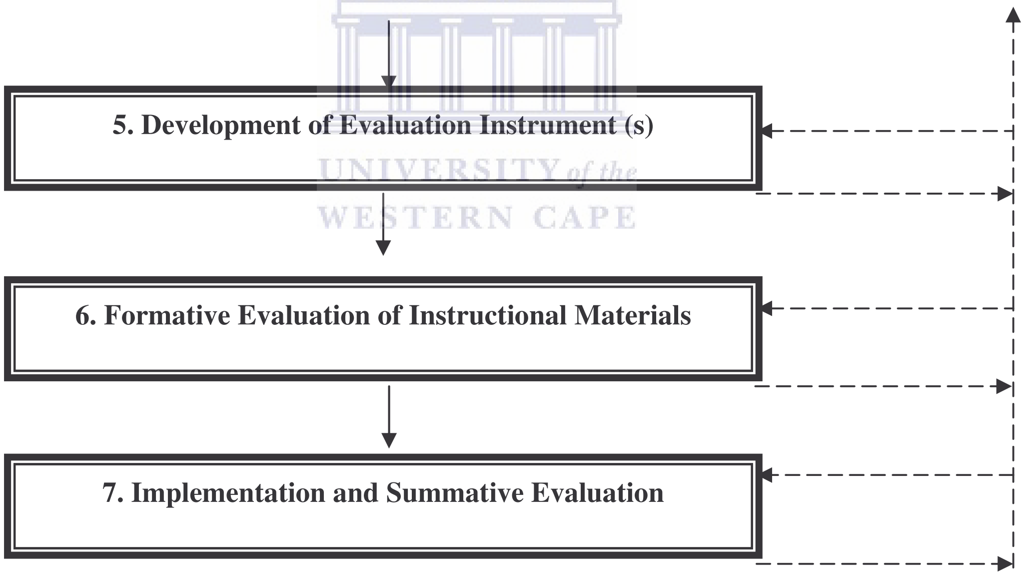


**Figure 5.1** The revised version of Ally's (1997) instructional design model developed after the study became more informed through practical experience resulting from insights during the study. Figure 5.2 serves to elaborate on the meaning of the double headed arrows in Figure 5.1

The initial assumption was that the model would have the cyclic or developmental motions confined to activities occurring between the various stages of the model. However, experience during the study suggested more cyclic motions within the individual stages and this is what is now reflected by the double headed arrows featuring where we started with single headed arrows (see Figure 5.1). Figure 5.2 elaborates on this and helps to explain the meaning of the double headed arrows in Figure 5.1. The reason why these illustrations have been presented here is to share the important lesson regarding developmental research, where there is never an end to the developmental process (be it human or product development), as noted by Dewey, (1964).






<u>NOTE</u>**:** The 'CYCLIC' process goes on and on within all and between the seven stages upwards

**Figure 5.2** Explanation of the double headed and dashed arrows in the revised version of the instructional design model in Figure 5.1

The two arrows in Figure 5.2, going in opposite directions show the actual movement and sense of activities represented by the double headed arrows in Figure 5.1, at every stage.

## 5.3 RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

From the experiences and insights gained during the course of this study, it is appropriate to give a few ideas for the purpose of further research, picking from issues that were found interesting, though beyond the scope of this study. Such issues were outside the parameters of the present research questions and were therefore evidence of the extent to which this study was limited. The ideas are hereby presented in the form of specific recommendations and suggestions under the following categories: MS within D&T education, Developmental research in relation to instructional design, and D&T education in relation to the professional development of teachers.

### *5.3.1 Recommendations and suggestions for MS within D&T education*

Learning from Hodson's (1992) views regarding the redefinition and reorientation of practical work in Science, it interesting to note the many similarities with what one would have under D&T. Just like Hodson investigates the exact status of practical work in science, the task has been the same in this study, where I have tried to determine the exact place for practical work in D&T, in an effort to relate theory and practice therein. Hodson (1992) thinks of education in science as having the following aspects; 'learning science', 'learning about science', and 'doing science'. Similarly, In this study I thought Material Science (MS) within Design and Technology (D&T) as fitting under the following categories; 'learning Material Science' 'learning about Material Science', and 'doing Materials Science'. Respectively, the following meanings were generated for the sake of clarity in each case:

*Learning Materials Science* involves the acquisition of a range of scientific concepts and becoming familiar with some of the proper and major scientific theories and principles relating to materials.

*Learning about Material Science* involves one gaining some understanding of the nature of material science and scientific practice, and an appropriation of the complex relationships between science, technology and society.

*Doing Materials Science*, involves the acquisition of knowledge and skills necessary for engaging in scientific inquiry and using that expertise to conduct real investigations, either self-directed or under the guidance of the teacher/lecturer.

Given the profiles of these categories and the challenges involved, perhaps the task for future research would be for one to find out and determine ways of striking or ensuring a balance between these functions as regards the application of Material Science (MS) within the context of D&T. As far as learning MS is concerned, perhaps we also need to change our perception of the primary purpose of practical work, as suggested by Hodson (1992) in respect of Science. Instead of being used to assist the concrete to become abstract, as most of us (teachers) usually insist, practical work should perhaps be used to furnish an opportunity to give concrete illustrations and representations to prior abstractions. In this case, the ideal would be to have 'theory' coming first before laboratory work or workshop activities which would then be used to assist the exploration, manipulation and development of concepts and to make the concepts manifest, comprehensible and useful. It is the exploration of ideas that constitutes the learning process; bench work simply provides the concrete evidence of the outcome of that conceptual exploration. According to Hodson (1992), successful learning requires lengthy and repeated contact with that which is to be learned; in this case, with the abstract ideas. All these views about the place of practical work in D&T would need to be checked and proved through further research.



### *5.3.2 Recommendations and suggestions for developmental research in relation to instructional design*

At this point, there are calls for: more observations of workshop activities, trying the concept of instructional resource packages with more elements of D&T, the possibility of adapting the instructional materials used in this study for distance education purposes and pupil/student participation in course design and development.

**More observations of workshop activities required**

Although observations were made during the Machine Shop Practice (MSP) course in order to check on whether or not teachers were using their knowledge of Material Science (MS) to solve practical D&T problems, the time was not enough. Both, MS and MSP ran for only 60 hours each. Perhaps it would have been more helpful to observe these practitioners for longer periods in their normal working environments within schools. Further research through tracer studies, aimed at observing teachers in action over periods of at least a year is required. Zimpher (1974) proposes this as one of the many ways in which teachers' actual activities in schools could realistically be evaluated. In the Zimbabwean context, this approach is likely to yield positive and meaningful results, since experiences are also likely to differ from school to school around the country. It is hoped that this would in turn yield a more realistic picture regarding the impact of teaching MS under D&T on the perceptions, understanding and knowledge of pupils in various contexts. According to observations from literature (Section 2.2), this recommendation is actually in line with Gorman and Hamilton's (1975) position, suggesting follow up studies where graduating teachers are studied in their working environments.



**Need to try the concept of the instructional resource package with more elements of D&T**

The instructional materials developed for this study were found effective for the purpose that they were designed for under the given circumstances; contributing towards the professional development of teachers. In Chapter 1, it was made clear that the way this course was designed and run in conjunction with the relevant instructional materials was on an experimental basis. Even the instructional package was considered a typical example applied on one specific course (MS) among the many that could have been handled under D&T. It would be interesting to find out if the same approach could in future be tried with more elements, like; mechanisms, structures, electronics, control systems, hydraulics and pneumatics. Further research to find out how these elements could be developed into individual courses might be helpful, bearing in mind assertions by Raudenbush, Eamsukkawat, Di-Ibor, Kamali and Taoklam (1993), maintaining that, the kinds of instructional materials available to teachers usually influence the rate at which they learn the subject matter and develop pedagogical skills. In addition, Lockheed, Vail and Fuller (1986) have also argued that texts and related materials may provide teachers with a more structured and comprehensive representation of the subject than would otherwise be available to them. Like what happened in the current study, such research would perhaps also need to run along the lines of an experiment which could be evaluated at the end. It might be too expensive to do this with several courses at one time. Therefore, this could go in stages where one course is taken at a time, just like this study was designed to deal with one course.

Although it was not a problem in this study, it will definitely be necessary to check on the question of ethical issues regarding such experiments. For example, there could be potential participants who might not feel comfortable to be treated as guinea-pigs. From an ethical point of view, the best approach would be to find a way of checking on the whole issue. In this study, the purpose of study was thoroughly explained to the participants. On most activities, they volunteered to participate in the project. Although the approach worked for this study, to be on the safe side, those who might be interested in following a similar approach, perhaps the idea would be to check on specific areas of concern regarding ethical issues depending on specific groups of participants.



**The possibility of adapting the instructional materials used in this study for distance education purposes**

Still on the issue of instructional materials, another avenue for further research could be to find out if it is possible to get the materials adapted for use by or with the Zimbabwe Open University which runs mainly on modular courses. Considering that the instructional materials used in this study were almost a complete package of modular materials, one could perhaps find out how the materials could be adjusted and developed for distance education purposes.

Another possibility along similar lines would be a trial of these materials within the Department of Technical Education at the University of Zimbabwe, which is now on a drive to go more towards teaching on a part-time basis. Similar developments as recommended for the Zimbabwe Open University could be tried in the Department before even going out. Although in this study the materials were used for a full time residential programme where teachers were able to work in groups with a lot of chances to meet and consult their resource persons and even their lecturer(s) whenever they chose to, it will be interesting to find out how the materials could be used with student teachers enrolled on a part-time basis. There is definitely a potential for these materials being developed and adapted for more private use and individualised instruction with part-time students/teachers enrolling for the B.Ed. degree in relevant programmes.

**A call for pupil/student participation in course design and development**

In this study, the active involvement and participation of teachers in the design, development, implementation and evaluation of the instructional materials was a fruitful experience. Given the successes scored in this study using this approach, the suggestion or proposition for further research is perhaps to try a similar approach with pupils/students in the learning of D&T in schools. Currently, the problem in most of our schools in Zimbabwe is that, due to the teachers' slavish adherence to the traditional approach of teaching technical subjects, workshop activities have usually been treated like a means of obtaining factual information or data, rather than a way of exploring and developing conceptual understanding. Hence pupils/students have usually been excluded from the designing and planning of experimental investigations and other related activities. According to Hodson (1992), failure to engage pupils/students in the thinking that precedes an experimental investigation renders much of the ensuing workshop activities pedagogically useless. Therefore, there is a need for further research to determine the best way of addressing the situation by actively engaging pupils/students in the best possible ways.

### *5.3.3 Recommendations and suggestions for D&T education in relation to the professional development of teachers*

Under this sub-section, there is need for more research in order to determine and consider; the influence of other factors on the perceptions, understanding and knowledge of teachers, the possibility of developing teachers into effective teams of teacher-researchers and the possibility of developing a similar programme of instruction at M.Ed degree level.

**Influence of other factors on the perceptions, understanding and knowledge of teachers**

Further research is recommended to find out whether or not teachers' perceptions of the D&T approach, understanding and knowledge of concepts in MS are influenced by their teaching experience, age, college of initial teacher training and type or location of school (e.g. rural, urban and peri-urban). Originally, there was a research question aimed at addressing this issue although it was later found not feasible within the scope and practical parameters of this study.



**The possibility of developing teachers into effective teacher-researchers**

From the design of this study, the way it progressed and from its achievements, I could as well be labelled and described as a 'teacher researcher'. The study was centred on the groups of teachers that I normally teach at the University of Zimbabwe, and D&T is my usual subject with similar groups. Judging by what was achieved or realized; one can safely declare the study a reasonable success. Given this background, perhaps it will be worthwhile to pursue this line of research by finding out how the teachers who were involved in this study could also be assisted in order to develop into effective, collaborative teacher-researchers. It will also be very interesting to find out how such a move would influence their activities as professionals in schools.

In my case, I took this path or line of thinking after being influenced and persuaded by the likes of Piaget (1980); Nixon (1987); Bauersfeld (1988); Cobb, Wood and Yackel (1990); Hargreaves (1996); Vygotsky (1987); Scott, (1998) Mortimer (1998); Kress, Jewitt, Ogborn and Tsatsarelis (2001); Viennot (2001) and Leach & Scott (2002), whose constructivist views and approaches to the teaching and learning of subjects like mathematics and science were very convincing in every sense. In most of their deliberations these authorities have celebrated the achievements of the teacher-researcher in most schools. Generally, from most of their discussions, there appears to be a growing body of evidence demonstrating that the manner in which pupils/students learn particular subject concepts (e.g. in mathematics and science) can be improved as a results of implementing research-based teaching styles and/or sequences.

**The possibility of developing a similar programme of instruction at M.Ed degree level**

While in this study, research was confined to the B.Ed intake, future research could perhaps be designed to find out if similar trials or experimental studies could also be done to cover the M.Ed. degree programme in the same department (Department of Technical Education at the University of Zimbabwe). One could start with subject areas along similar lines before broadening and checking with other subject areas.

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# APPENDICES

## **<u>Appendix 1</u>:** Syllabi check-list after completion

**<u>CHECH-LIST</u>**: The extent to which the Aims, Objectives, and Content items in the ‘A’ Level Design and Technology syllabus agree with those in the ‘O’ Level Metal/Woodwork syllabi.

| **ITEMS AND ATTRIBUTES IN ‘A’ LEVEL SYLLABUS** | **M/W** | | **W/W** | |
|---|---|---|---|---|
| | **Y** | **N** | **Y** | **N** |
| **A. <u>AIMS</u>**:- Students should be encouraged to; | | | | |
| - develop/sustain innovation, creativity and design and technology capability. | √ | | √ | |
| - develop awareness of the significance of design and technology in society. | | √ | | √ |
| - apply knowledge, understanding and skills to a range of technological activities. | | √ | | √ |
| - develop an understanding of industrial practices. | √ | | √ | |
| - use information and communication technology appropriately to enhance their design and technology capability. | √ | | | √ |
| - develop critical evaluation skills in technical, aesthetic, economic, environmental, social and cultural contexts. | √ | | √ | |
| - develop as discerning consumers able to make informed choices. | √ | | | √ |
| - develop positive attitudes of co-operation and citizenship and work collaboratively. | √ | | √ | |
| **B. <u>OBJECTIVES</u>** | | | | |
| **(a)** <u>Knowledge and Understanding</u>:- Students should demonstrate knowledge and understanding in relation to; | | | | |
| - materials and components for the production of artefacts. | √ | | √ | |
| - tools (equipment) and associated processes in design and technology. | √ | | √ | |
| - the impact of design and technology upon society. | | √ | | √ |
| - communication using a range of graphical techniques including conventions and specialist vocabulary. | √ | | √ | |
| **(b)** <u>Design Analysis</u> (generation of ideas & synthesis)- Students should be able to; | | | | |
| - prepare a design brief relating to a situation of need. | | √ | √ | |
| - search out, select and order information relevant to a design problem. | √ | | √ | |
| - analyse situations of need and produce a specification of requirements, taking account of human, aesthetic, and environmental factors. | √ | | | √ |
| - generate and explore a range of conceptual ideas. | | √ | | √ |
| - appraise ideas leading to the selection and modelling of a design proposal. | | √ | | √ |
| - refine and develop in detail a design proposal suitable for implementation, recognising constraints of time, cost and available resources. | √ | | √ | |
| **(c)** Practical Implementation:- Students should be able to; | | | | |
| - plan and organise the procedure to implement a design proposal. | | √ | √ | |

| | | | | |
|---|---|---|---|---|
| - safely and efficiently undertake specific practical activities in design. | √ | | √ | |
| - demonstrate refined making skills and capacity to attend to fine detail. | √ | | | √ |
| - test and evaluate products before proposal for improvement. | √ | | | √ |
| **C. <u>CONTENT</u>**:- Content would include the following: | | | | |
| - The theory of design and technology | | √ | | √ |
| - Analysis of problem situation | √ | | √ | |
| - Preparation of a design brief | √ | | √ | |
| - The design process | √ | | √ | |
| - Recording information | √ | | √ | |
| - Graphic communication and drawing systems | √ | | √ | |
| - Research for possible solutions to given problems | √ | | √ | |
| - Development of chosen solutions to given problems | √ | | √ | |
| - Modelling and testing of ideas and/or proposals in design | √ | | √ | |
| - Product development and realisation | √ | | √ | |
| - Presentation of products in design (e.g. displays and exhibitions) | | √ | | √ |
| - Mandatory and safety measures in design | √ | | √ | |
| - Organisation of resources in design | | √ | √ | |
| - Testing and evaluation in product design | √ | | √ | |
| - Design and technology in society | | √ | | √ |
| - Aesthetics in design | | √ | √ | |
| - Ergonomics in design | | √ | | √ |
| - Energy (forms and sources) | | √ | | √ |
| - Conversion and transmission of energy (e.g. mechanisms) | | √ | | √ |
| - Principles of control (manual, semi-auto & automatic) | | √ | | √ |
| - Electronics and control (including circuit design) | | √ | | √ |
| - Computer aided design and manufacture | | √ | | √ |
| - Material Science (e.g. nature and properties) | √ | | | √ |
| - Materials processing | √ | | | √ |
| - Product analysis (function, aesthetics, ergonomics, materials, production techniques and safety of existing products) | | √ | √ | |
| - Health and safety | √ | | √ | |
| - Decision making in design | √ | | √ | |
| - Tool technology | √ | | √ | |

| | | | | |
|---|---|---|---|---|
| - Technological design and production | | √ | √ | |
| - Mechanisms | √ | | √ | |
| - Structures | | √ | √ | |

## **Appendix 2:** Learner Analysis Questionnaire (Questionnaire 'A')

This questionnaire is mainly about your initial teacher training and the extent to which you got familiar with 'Design and Technology', both as an **approach** and as a **subject**. It also seeks your opinion on items that could comprise a proposed in-service teacher education program where you could also participate as a resource person. Please provide the required information by **writing** and **ticking** as appropriate.

**(A) DEMOGRAPHIC DATA**

1. Age: ___ 2. Gender (M/F): ___ 3. College of initial training: __ 4. Period of training: __ 5. Qualification (s) obtained: __ 6. Main subject(s) trained for: __ 7. Subject(s) currently teaching: ___ 8. No. of years teaching: __ 9. Sch. currently teaching: _____ 10. District sch. is situated: _______ 11. Location of sch., rural or urban: ___ 12. Your subject in B.Ed program: __.

**(B) INITIAL TEACHER TRAINING**

1. Elements **(a)** to **(g)** are taken from the 'O' Level Woodwork and Metalwork syllabi. Indicate by ticking in the appropriate box, the extent to which you feel your teacher training prepared you to handle them when assisting pupils at 'O' Level (where: **1** = NOT AT ALL; **2** = NOT QUITE; **3** = UNDECIDED; **4** = WELL ENOUGH; **5** = VERY WELL).

| COURSE ELEMENTS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| (a) The theory of Design and Technology | | | | | |
| (b) Materials Science | | | | | |
| - Evolution and nature of materials | | | | | |
| - Materials and their properties | | | | | |
| - Materials processing | | | | | |
| - Materials and process selection | | | | | |
| (c) Mechanisms and motion | | | | | |
| (d) Structures (types and designs) | | | | | |
| (e) Pneumatics | | | | | |
| (f) Hydraulics | | | | | |
| (g) Graphic communication | | | | | |

2. Any comments: ________________________________________________________

**(C) RELATING 'O' and 'A' LEVEL SYLLABI (Regarding D&T)**

1. On elements **(a)** to **(g)**, found in the Woodwork and Metalwork 'O' Level syllabi, indicate by ticking appropriately, the extent to which you feel they could be pre-requisite to what you will encounter in your teaching of Design and Technology at 'A' Level (Where: **1** = NOT AT ALL; **2** = NOT QUITE; 3 = FAIRLY SO; **4** = MUCH SO; 5 = VERY MUCH).

| COURSE ELEMENTS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| (a) The theory of Design and Technology | | | | | |
| (b) Material Science | | | | | |
| (i) Evolution and nature of materials | | | | | |
| (ii) Materials and their properties | | | | | |
| (iii) Materials processing | | | | | |
| (iv) Materials and process selection | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| (c) Mechanisms and motion | | | | | |
| (d) Structures (types and designs) | | | | | |
| (e) Pneumatics | | | | | |
| (f) Hydraulics | | | | | |
| (g) Graphic communication | | | | | |

2. Any comments: ____________________________________________________________.

**(D) YOUR OPINION ON ITEMS FOR THE PROPOSED IN-SERVICE PROGRAMME**

1. Elements **(a)** to **(p)** are taken from the 'A' Level Design and Technology syllabus. Indicate the ones you feel should be included in an in-service program designed for teachers in your subject area(s). Also, considering the issue of relevance and appropriateness within the Zimbabwean context, determine the degree of importance by observing the following scale: **1** = NOT AT ALL IMPORTANT; **2** = NOT QUITE IMPORTANT; **3** = FAIRLY IMPORTANT; **4** = IMPORTANT; **5** = VERY IMPORTANT

| **COURSE ELEMENTS** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| (a) The theory of Design and Technology | | | | | |
| (b) Materials Science | | | | | |
| - Evolution and nature of materials | | | | | |
| - Materials and their properties | | | | | |
| - Materials processing | | | | | |
| - Materials and process selection | | | | | |
| (c) Structures (types and designs) | | | | | |
| (d) Stress analysis | | | | | |
| (e) Mechanisms and motion | | | | | |
| (f) Energy and dynamics | | | | | |
| (g) Thermodynamics | | | | | |
| (h) Fluid mechanics | | | | | |
| (i) Electricity and electronics | | | | | |
| (j) Analogue signal processing | | | | | |
| (k) Digital signal processing | | | | | |
| (l) Control systems | | | | | |
| (m) Pneumatics | | | | | |
| (n) Hydraulics | | | | | |
| (o) Computer control | | | | | |
| (p) Graphic communication | | | | | |



2. Where necessary, give reasons for your responses: ______________________________

**(E) INDICATION OF WILLINGNESS TO ACT AS RESOURCE PERSON**

1. In the event of the establishment of a major project aimed at the development of an in-service program for teachers in areas relating to Design and Technology, would you be interested in acting as one of the resource persons, expected to facilitate discussion and make presentations during some planned seminars? **Yes** or **No**: ________.

2. If your answer to item '1' is 'Yes', indicate or show the degree of your interest on specific areas, depending on which ones you would possibly like to be involved in, from **(a)** to **(p)**. Follow the given scale, where: **1** = NOT AT ALL INTERESTED; **2** = NOT QUITE INTERESTED; **3** = FAIRLY INTERESTED; **4** = INTERESTED; **5** = VERY INTERESTED.

| **COURSE ELEMENTS** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| (a) The theory of Design and Technology | | | | | |
| (b) Materials Science | | | | | |
| (i) Evolution and nature of materials | | | | | |
| (ii) Materials and their properties | | | | | |
| (iii) Materials processing | | | | | |
| (iv) Materials and process selection | | | | | |
| (c) Structures (types and designs) | | | | | |
| (d) Stress analysis | | | | | |
| (e) Mechanisms and motion | | | | | |
| (f) Energy and dynamics | | | | | |
| (g) Thermodynamics | | | | | |
| (h) Fluid mechanics | | | | | |
| (i) Electricity and electronics | | | | | |
| (j) Analogue signal processing | | | | | |
| (k) Digital signal processing | | | | | |
| (l) Control systems | | | | | |
| (m) Pneumatics | | | | | |
| (n) Hydraulics | | | | | |
| (o) Computer control | | | | | |
| (p) Graphic communication | | | | | |



3. Any comments ___________________________________________________________.

**(F) ANTICIPATED LOGISTICAL AND PRACTICAL PROBLEMS**

1. Indicate by ticking appropriately, the degree to which you agree or disagree with the following being anticipated problems in the teaching and learning of Design and Technology at 'A' Level, with specific reference to your situation (where:**1** = STRONGLY DISAGREE; **2** = DISAGREE; **3** = UNDECIDED; **4** = AGREE; **5** = STRONGLY AGREE

| ANTICIPATED PROBLEMS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| (a) Lack of relevant literature | | | | | |
| (b) Lack of relevant equipment | | | | | |
| (c) Lack of facilities, especially laboratories and workshops | | | | | |
| (d) Lack of relevant materials (e.g. wood, metal and plastic) | | | | | |
| (e) Inadequate time being allowed on the time table | | | | | |
| (f) Lack of support from teachers/instructors of other subject areas | | | | | |
| (g) Unsafe working conditions | | | | | |

2. Any comments: ______________________________________________________.

## **Appendix 3 :** Pre & Post-Test Questionnaire (Questionnaire ‘A2’)

**(A) Demographic Data**

1. Candidate No. : _____ (if you wish) 2. Age: ____ 3. Gender (M/F): ___. 4. College of initial tr. training: ____5. Period of training (what yr. to what yr):___ 6. Qualification (s) obtained: ___ 7. Main subject (s): ___ 8. Subject currently taught: ____ 9. Years in teaching profession: ___ 10. Sch. where currently teaching: ___. 11. District where school is situated: ___. 12. Location of school (rural/urban): ___ 13. Your area of study in the B.Ed. program: ___.

**(B) Perceptions on Selected Items**

Using the provided scale, indicate the extent to which you agree or disagree with the following statements in relation to the teaching and learning of Material Science within the context of Design and Technology.

Scale: **1** - STRONGLY DISAGREE; **2** – DISAGREE; 3 – UNDECIDED; 4 – AGREE; 5 – STRONGLY AGREE.

| **STATEMENTS** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| 1. When teaching and learning Material Science, to get focused, there should be no interference from other areas through the so-called subject integration. | | | | | |
| 2. Since Material Science is closely linked to Machine-Shop Practice, there is no relationship with Physics and Chemistry; subjects whose practical activities are confined to the laboratory. | | | | | |
| 3. Given so much to cover in Material Science and in view of the shortage of time, the lecture method is the best way to teach it. | | | | | |
| 4. The problem with group activities in the teaching and learning of Material Science is that learners end up copying each other’s work, thereby resulting in very little individual effort. | | | | | |
| 5. Having Woodwork and Metalwork under the same roof does not allow for depth of learning in each of these disciplines. | | | | | |
| 6. Material Science is a very difficult and serious subject where the teacher should be in charge of events during the teaching and learning process if there is to be any progress. | | | | | |
| 7. For reliable assessment of pupils’ work in Design and Technology the teacher should always be objective and should not allow for pupil self-assessment. | | | | | |
| 8. Allowing for pupils’ self-assessment usually results in unnecessary disagreements between the teacher and his/her pupils. | | | | | |
| 9. There is a lot of Material Science implied within traditional subjects like Woodwork and Metalwork. | | | | | |
| 10. The problem of engaging pupils in brainstorming over design issues is that order is disrupted resulting in chaotic classrooms. | | | | | |
| 11. Working on mock-ups is as challenging as working on actual artifacts in terms of problem solving in Design and Technology. | | | | | |
| 12. Material Science is not suitable for teaching and learning at levels lower than ‘A’ Level. It is too difficult and would confuse pupils. | | | | | |
| 13. For one who specializes in wood or metal, learning about other materials is a sheer waste of time and resources since s/he rarely uses other materials. | | | | | |
| 14. It is possible to describe the properties of materials effectively through common sense. | | | | | |
| 15. Having Design and Technology at ‘A’ Level instead of Woodwork and Metalwork is an unfortunate development since learners would not have the opportunity to advance themselves | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| in those two important subject areas. | | | | | |

**(C) Knowledge of Materials**
Using the provided scale, indicate the extent to which you agree or disagree with the following statements relating to materials. Scale: **1** - STRONGLY DISAGREE; **2** - DISAGREE; **3** - UNDECIDED; **4** - AGREE; **5** - STRONGLY AGREE

| STATEMENTS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Different materials have the same type of atom. The only difference is in the arrangement of the atoms in various materials. | | | | | |
| 2. Electrons differ, depending on the types of materials. | | | | | |
| 3. In hot weather, wooden structures expand due to heat absorption. | | | | | |
| 4. All known matter on earth is represented in the periodic table. | | | | | |
| 5. The melting point of any metal in Sweden differs from that in Zimbabwe due to differences in weather conditions, with the former being colder than the latter. | | | | | |
| 6. When metals are heated, they expand due to the increase in atoms per unit cell. They absorb more atoms from the heat. | | | | | |
| 7. The main disadvantage of all plastics is that they soften when heated. | | | | | |
| 8. The effects of moisture absorption and loss are equal in all the dimensions in a piece of wood. | | | | | |
| 9. On cooling, metals shrink due to the loss of atoms. | | | | | |
| 10. The rate of expansion of a bar of iron differs, depending on where you are; hot or cold regions of the world. | | | | | |
| 11. Steel is used for reinforcement in concrete structures because it elongates at the same rate with concrete. | | | | | |
| 12. Just like in copper, cold working raises the hardness level of lead. | | | | | |
| 13. In hot weather, asphalt becomes very hard due to the effects of heat. | | | | | |
| 14. A piece of wood has the same strength qualities all round. | | | | | |
| 15. Zinc and copper do not corrode at all in the atmosphere. | | | | | |
| 16. In a bar of metal, the rate of expansion differs, depending on the orientation in terms of dimensions (e.g. length and width). | | | | | |
| 17. The higher the temperature in semi-conductors, the higher the electrical conductivity. | | | | | |
| 18. The diameter of an atom depends on the number of electrons around the nucleus. | | | | | |
| 19. The weight of an atom is mainly determined by the nucleus. | | | | | |
| 20. The volume of an object has a direct link to its (object) density. | | | | | |
| 21. There is a strong correlation between hardness, tensile strength and cold work when dealing with metals. | | | | | |
| 22. Plastics are totally different from metals and the methods of processing them are also different. There are no similarities at all. | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 23. Plastic strain results in temporary deformation in metals. | | | | | |
| 24. Solid solution copper is one grade of pure copper. | | | | | |
| 25. Because of its density, magnesium is a lot heavier than aluminum. | | | | | |
| 26. Recent explorations have revealed massive deposits of magnesium in the sea. | | | | | |
| 27. There are some softwoods that are much harder than some hardwoods. | | | | | |
| 28. Diamond is one of the hardest metals used in tool making. | | | | | |
| 29. The electrical conductivity of copper increases with more solid solution. | | | | | |
| 30. Given its high strength, carbon steel makes the most durable and reliable bushes for use in starter motors. | | | | | |

**(D) Level of Confidence on Selected Items**
Material Science is a major component of Design and Technology. From items 1 to 7, indicate your level of confidence if you were to teach this area at 'A' Level. Use the following scale: **1** - NOT AT ALL; **2** - NOT QUITE CONFIDENT; **3** - FAIRLY CONFIDENT; **4** - CONFIDENT; **5** - VERY CONFIDENT.

| STATEMENTS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **1. ENGINEERING MATERIALS IN GENERAL** | | | | | |
| (a) Three main families of engineering materials | | | | | |
| (b) Bonding forces in different materials | | | | | |
| **2. METALLIC STRUCTURES** | | | | | |
| (a) Metal atoms | | | | | |
| (b) The periodic table | | | | | |
| (c) The unit cell | | | | | |
| (d) Phase transformation in metals | | | | | |
| (e) Effects of other element on the structure of pure metals | | | | | |
| **3. EFFECTS OF STRESS AND TEMPERATURE ON METALS** | | | | | |
| (a) Plastic strain, permanent deformation and slip | | | | | |
| (b) Cold work or work hardening | | | | | |
| (c) Effects of elevated temperatures on work hardened structures | | | | | |
| (d) Selection of annealing temperatures | | | | | |
| (e) Effects of grain size on properties | | | | | |
| **4. ENGINEERING ALLOYS (Non-ferrous)** | | | | | |
| (a) Aluminum alloys | | | | | |
| (b) Magnesium alloys | | | | | |
| (c) Copper alloys | | | | | |
| (d) Nickel alloys | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| (e) Titanium alloys | | | | | |
| (f) Zinc alloys | | | | | |
| **5. STEEL, CAST IRON, DUCTILE IRON and MALLEABLE** | | | | | |
| (a) The iron-iron carbide diagram and its phases | | | | | |
| (b) Plain carbon and low alloy steel (equilibrium structures) | | | | | |
| (c) Hypoeutectoid and hypereutectoid steels | | | | | |
| (d) Hardenability of steel | | | | | |
| (e) Stainless steels | | | | | |
| (f) White iron, gray iron, ductile iron and malleable iron | | | | | |
| **6. COMPOSITE MATERIALS; Including Concrete and Wood** | | | | | |
| (a) Synthetic composites | | | | | |
| (b) Concrete and its components | | | | | |
| (c) Properties of concrete | | | | | |
| (d) Special concretes | | | | | |
| (e) Wood as an engineering material | | | | | |
| (f) Wood macrostructure | | | | | |
| (g) Wood microstructure | | | | | |
| (h) Properties of wood | | | | | |
| (i) Asphalt as an engineering material | | | | | |
| **7. PLASTICS** | | | | | |
| (a) The concept of polymerization | | | | | |
| (b) Polymerization types | | | | | |
| (c) Processing of plastics | | | | | |

**Appendix 4**: Formative Evaluation Questionnaire (Questionnaire 'C')

**(I) DEMOGRAPHIC DATA**

1. Candidate No._____ (If you wish). 2. Your gender (M/F):___ 3. Group No. ___ 4. Module unit No. ___. 5. Tech. Subj. (s) you are currently studying ____.

**(II) OPINION ON VARIOUS ASPECTS IN UNIT**

1. For the purpose of improving this unit, please express your opinion by ticking in the appropriate box, from item **(a)** to **(o),** assuming the statements were yours.

SCALE: Strongly disagree **(1) -------------------------------- (5)** strongly agree

| **STATEMENTS** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| (a) I found the topic dealt with in this unit relevant to Design and Technology | | | | | |
| (b) This unit is very well introduced | | | | | |
| (c) This unit is very well structured and easy to follow | | | | | |
| (d) The unit objectives are very well stated | | | | | |
| (e) The objectives are adequately accommodated within the unit content | | | | | |
| (f) The content covered in this unit is very relevant and appropriate for the given topic | | | | | |
| (g) The unit is adequately summarized | | | | | |
| (h) I found the practice activity/activities relevant, appropriate and useful | | | | | |
| (i) I found the group activity/activities relevant, appropriate and useful | | | | | |
| (j) My self assessment was well directed | | | | | |
| (k) The section on 'Reflection' has been very useful as a way of consolidating my understanding of this unit. | | | | | |
| (l) The unit test adequately covered the unit content | | | | | |
| (m) Items in the unit test were clear and easy to follow | | | | | |
| (n) The unit test was very useful for revision purpose | | | | | |



3. Any other comments: ____________________________________________________.

**<u>Appendix 5</u>:** Summative Evaluation Questionnaire (Questionnaire 'D')

**(I) DEMOGRAPHIC DATA**

1. Candidate No. ___ (Only if you wish). 2. Your gender (male/female):___ 3. Group No. ____.

4. Technical subject(s) you are currently studying: ____.

**(II) OPINIONS ON VARIOUS ASPECTS IN Module/Program/Course**

1. For the purpose of improving the whole module/program or course, please express your opinion by ticking in the appropriate box, from item (**a**) to (**n**) assuming the statements were yours.

<u>SCALE</u>: Strongly disagree **(1) -------------------------------- (5)** strongly agree

| STATEMENTS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| (a) This whole module or program is very relevant for teaching Design and Technology at 'A' Level | | | | | |
| (b) The time (60 hours) allowed for this module/program or course is adequate | | | | | |
| (c)The overall course aims have been clearly stated and are easy to follow | | | | | |
| (d) The overall course objectives have been clearly stated and are easy to follow | | | | | |
| (e) The overall course aim(s) has/have been adequately accommodated within the content | | | | | |
| (f) The overall course objectives have been adequately covered within the content | | | | | |
| (g) The course outline for this program has been easy to follow | | | | | |
| (h) The module has been very well structured, right from the content page | | | | | |
| (i) The sequence of various units has been very easy to follow | | | | | |
| (j) I think what I learnt in this course (program) is going to be very useful in the event that I teach Design and Technology at 'A' Level | | | | | |
| (k) The various units in this module have been adequately introduced | | | | | |
| (l) The various units in this module have been adequately summarized | | | | | |
| (m) The practice and group activities have been generally relevant, appropriate and useful | | | | | |
| (n) The unit tests have been generally useful for revision purposes | | | | | |
| (o) The overall module test has given full coverage of the whole course | | | | | |

2. Any other comments: ________________________________________________________.

**Appendix 6:** The instructional resource package (Course outline)

**D&T.ED. MODULE No. DTEMOD3: MATERIAL SCIENCE** (Evolution & nature of materials, Materials & their properties, Materials processing and Materials & process selection)

**Module Time**: 60 hours

**Overall Course Aim(s)**

The main purpose of this course is to give **you** (prospective Design and Technology teachers) a strong theoretical background that would enable them to teach Material Science at 'A' Level. Although this course is mainly theoretical, an effort will be made to engage learners in simple illustrations, demonstrations and laboratory activities wherever relevant and appropriate.

**Overall Course Objectives**

By the end of this course, **you** should be able to do the following:

- identify the atomic structure of various elements (materials);

- place the various engineering materials into their respective family groups, **metallic**, **ceramic**, and the **polymeric**;

- relate the atomic structures of various elements (materials) in the periodic table;

- highlight the uses or engineering applications of various materials;

- identify the methods usually used to process various materials;

- identify properties of various engineering materials;

- explain the differences and similarities between various materials in terms of properties;

- specify relevant and appropriate materials for specific projects and industrial applications; depending on particular properties;

- recommend appropriate tools or equipment (technology) for use on various materials, depending on their particular properties;

- recommend appropriate methods of processing various materials.

## CONTENTS

UNIT 1: **THE THREE FAMILIES OF ENGINEERING MATERIALS**

1.0 Introduction

1.1 Unit Objectives

1.2 Unit Content

1.2.1 The structure of materials (Bonding forces in different materials)

3.0 Introduction

3.1 Unit Objectives

3.2 Unit Content

3.2.1 Effects of stress on metal structures

3.2.2 Plastic strain, permanent deformation and slip

3.2.3 Cold work or work hardening

3.2.4 Methods of work hardening

3.2.5 Effects of elevated temperatures on work hardened structures

3.2.6 Recovery, recrystallization and grain growth

3.2.7 Selection of annealing temperatures

3.2.8 Effects of grain size on properties

3.2.9 Engineering applications of cold work and annealing

3.2.10 Hot working; rolling, forging, drawing, extrusion and spinning

3.3 Unit Summary

3.4 Practice Activity or Activities

3.5 Group Activity or Activities

3.6 Self Assessment

3.7 Reflections

3.8 Unit Test 3



UNIT 4: **ENGINEERING ALLOYS** (Non-ferrous)

4.0 Introduction

4.1 Unit Objectives

4.2 Unit Content

4.2.1 Processing methods in general

4.2.2 Aluminium alloys

4.2.3 Magnesium alloys

4.2.4 Copper alloys

4.2.5 Nickel alloys

4.2.6 Titanium alloys

4.2.7 Zinc alloys

4.2.8 The less common metals (precious metals)

4.3 Unit Summary

4.4 Practice Activity or Activities

4.5 Group Activity or Activities

4.6 Self Assessment

4.7 Reflection

4.8 Unit Test 4

UNIT 5: **STEEL, CAST IRON, DUCTILE IRON and MALLEABLE IRON**

5.0 Introduction

5.1 Unit Objectives

5.2 Unit Content

5.2.1 Introduction to iron alloys

5.2.2 The iron-iron carbide diagram and its phases

5.2.3 Plain carbon and low alloy steels (equilibrium structures)

5.2.4 Steels (hypoeutectoid and hypereutectoid)

5.2.5 Effects of carbon on transformation of austenite and transformation products

5.2.6 Quenching and the need for alloy steels

5.2.7 Hardenability (properties of plain carbon and alloy steels)

5.2.8 Stainless steels

5.2.9 White iron, grey iron, ductile iron and malleable iron

5.2.10 Importance of high carbon alloys

5.3 Unit Summary

5.4 Practice Activity or Activities

5.5 Group Activity or Activities

5.6 Self Assessment

5.7 Reflections

5.8 Unit Test 5

UNIT 6: **COMPOSITE MATERIALS, INCLUDING CONCRETE AND WOOD**

6.0 Introduction

6.1 Unit Objectives

6.2 Unit Content

6.2.1 Synthetic composites

6.2.2 Composite strengthening by dispersion, particle reinforcement and fibre reinforcement

6.2.3 Concrete and its components

6.2.4 Properties of concrete

6.2.5 Special concretes

6.2.6 Reinforced and pre-stressed concrete

6.2.7 Proportioning of concrete mixtures

6.2.8 Introduction to wood as an engineering material

6.2.9 Wood macrostructure

6.2.10 Wood microstructure

6.2.11 Properties of wood

6.2.12 The role of defects in lumber

6.2.13 Asphalt as an engineering material

6.3 Unit Summary

6.4 Practice Activity or Activities

6.5 Group Activity or Activities

6.6 Self Assessment

6.7 Reflections

6.8 Unit Test 6

UNIT 7: **PLASTICS** (High Polymers)

7.0 Introduction

7.1 Unit Objectives

7.2 Unit Content

7.2.1 Polymeric structures

7.2.2 Polymerisation types

7.2.3 Processing plastics (methods)

7.3 Unit Summary

7.4 Practice Activity or Activities

7.5 Group Activity or Activities

7.6 Self-Assessment

7.7 Reflections

7.8 Unit Test 7

MODULE TEST (Units 1-7)

**Note**: Full details of course are available on CD and as a separate hard copy.

**Appendix 7:** Cohort '1' Interview guide (Application of MS within the MSP course)

**(A) DEMOGRAPHIC DATA**

**1.** Age: __ 2. Gender (M/F):__ 3. College of initial teacher training: __4. Period of training (what year to what year):__ 5. Qualification (s) obtained: __ 6. Main subject(s) trained for: __ 7. Subject(s) currently taught: ___ 8. Years in teaching profession: ____. 9. Sch. where you are currently teaching: ____10. District where school is situated: ___ 11. Location of school (rural or urban):___. 12. Your area of study in the B.Ed programme: ___.

**(B) QUESTIONS**

1. What would you say is the relationship between what you learnt in Material Science and what you are now learning in Machine Shop Practice?

2. In your learning of Machine Shop Practice, are you finding a chance or chances to apply what you learnt in Material Science? If so, in what way are you applying your Material Science in Machine Shop Practice?



3. Given your activities in Machine Shop Practice, where exactly would you say, there has been evidence of you having applied your knowledge of Material Science?

4. Could there be any problems that you are experiencing in your efforts tying to apply your Material Science within the context of your Machine Shop Practice course? If so, may you please elaborate?

5. At the end of your course, in what way do see yourself assisting pupils in their learning of Design and Technology, given what you have learnt in Material Science and what you are currently learning in Machine Shop Practice?

6. What problems do you foresee back at your school trying to implement what you would have learnt in your Material Science and Machine shop Practice courses by the end of your program of studies? If any, what would you say are possible solutions and how do you plan going around some of those problems?

**<u>Appendix 8</u>:** Cohort '2' Interview Guide (Views on the usefulness of MS during the examination)

**(A) DEMOGRAPHIC DATA**

1. Age: ___ 2. Gender (male/female): ___ 3. College of initial teacher training: ___ 4. Period of training (what year to what year):___ 5. Qualification(s) obtained: ___.6. Main subject(s) trained for: ___ 7. Subject(s) currently taught: ___. 8. Number of years in the teaching profession: ___ 9. Sch. where you are currently teaching: ___10. District where school is situated: ___ 11. Location of school (rural or urban):___ 12. Area of study in B.Ed: ____

**(B) PRE-PRACTICAL EXAMINATION INTERVIEW**

1. Very soon this semester, you are going to have a practical examination in Machine Shop Practice. How well prepared do you feel?

2. Ideally, what you have so far learnt or you are still learning in Machine Shop Practice should be reflective of what you learnt in Material Science. Do you anticipate this relationship in the oncoming practical examination?

(a) If 'YES', in what form?
(b) If 'NO', why do you say so?

3. Do you see what you learnt in Material Science being useful or applicable during this examination?



(a) If 'YES', in what way?
(b) If 'NO', why do you say so?

**(C) POST-PRACTICAL EXAMINATION INTERVIEW**

1. Now that the practical examination in Machine Shop Practice is over, to what extent do you feel satisfied with your performance during this examination?

2. Do you feel you were well or adequately prepared for this examination?

(a) If 'YES', please explain giving specific examples.
(b) If 'NO', why do you say so?

3. Did you find your Machine Shop Practice and Material Science courses reflective of each other during the just ended practical examination?

(a) If 'YES', in what way?
(b) If 'NO', why do you say so?

4. Did you find your knowledge of Material Science useful or applicable during this examination?

(a) If 'YES', in what way?
(b) If 'NO', why do you say so?

**<u>Appendix 9</u>:** An example a typical interview transcript extracted from the 40 page document of interview transcripts for Cohort 1 Interviews

**INTERVIEW 17**

**1. Demographic Data** (Introduction) **-** Interviewee is MALE.

- Interviewer (Wer): Good afternoon sir.
- Interviewee (Wee): Hello. Good afternoon.
- Wer: How are you doing?
- Wee: Ha-a, all right.
- Wer: And, how is school?
- Wee: Ha-a so, so. We are not aware of exactly what's happening at the present moment. Everything is upside down. People want to see the timetable, whether it's out or what, --- I don't know.
- Wer: Okay. I understand sir you are a teacher by profession.
- Wee: Yes, I am.
- Wer: Okay. E--, you're doing your B.Ed. right now and you're specializing in?
- Wee: In Wood Technology and Design.
- Wer: Okay. So, where did you do your teachers' training?
- Wee: I did my teachers' training at --- Gweru Teachers' College.
- Wer: How long was this?
- Wee: I think I'll try --- I trained from 1977 to 1979.
- Wer: It was 3 years then --- 77 to --- 3 years?
- Wee: 3 years.
- Wer: Okay, okay. So, you --- you obtained what --- what did you obtain?
- Wee: It was a Certificate in Education.
- Wer: Oh --- a CE. So, it's from what these guys are getting, like these guys from Belvedere.
- Wee: Ya-a, they are getting diplomas.
- Wer: Diplomas and NFCs and NFDs---. Okay. So, what are your main subjects that you teach?
- Wee: E-e ---, currently?
- Wer: No, on, no --- ya-a, currently, when you are teaching at your school?
- Wee: I am teaching Wood.
- Wer: Woodwork. So, you also majored in Woodwork at Gweru?
- Wee: I majored in Woodwork major and Metalwork minor. But you see, at --- GTC, we were being prepared to go and teach other subjects in schools apart from technicals, so we were covering Science, English, but I majored in Woodwork.
- Wer: So, in other words, for how long have you been teaching?
- Wee: Oh --- this must be my 24th year!
- Wer: Okay. So, for 24 years? So, your schools in --- is situated in Bulawayo or --- or?
- Wee: Bulawayo.
- Wer: Gwanda?
- Wer: Okay, okay. It's pleasing to --- it's pleasing to note. But I understand you are at college, university, you did your --- your, last semester --- this is your final semester, I believe?
- Wee: Yes.

**2. Questions** (The interview)

- Wer: And I believe last semester you did this course they call Materials Science.
- Wee: Yes. We did that.
- Wer: How do --- do --- did you find that?
- Wee: E --- that course Mr. Katiriri ---
- Wer: Okay ---.
- Wee: --- actually a---I --- I would say, I do not know why that course is not being properly introduced in secondary schools because it was really an eye opener.
- Wer: Okay, okay.
- Wee: I found it quite worthwhile.
- Wer: Okay, okay.
- Wee: I even wish we were given trips into some of these manufacturing companies in the city ---.
- Wer: Okay.
- Wee: --- so we see them really working on the materials.
- Wer: Also, you are really talking of the exposure --- like going to Redcliff where you can the see thing --- th- e- the material actually being put in the furnace, and you call it ---
- Wee: Yes, yes.
- Wer: --- like what they call the pealite structure and whatever?
- Wee: Yes, yes. That is what we were looking for.
- Wer: Okay, okay, aha-a. So, I understand now, as of now, you are doing Machine Shop Practice.
- Wee: Yes.
- Wer: Is there a relationship between the two, Machine Shop Practice and the Material Science that you learnt?
- Wee: There is.
- Wer: Aha.

- Wee: There is --- the --- there is definitely some relationship, because we --- you see, my --- my stay here at college, at the university has made me understand really how to work with materials like 'card'.
- Wer: Aha.
- Wee: I --- I will tell you, if you realize the way I do the cutting now ---
- Wer: Aha.
- Wee: --- it's much different from the previous time when I --- I started working on card ---
- Wer: Okay.
- Wee: --- but, Material Science is also making me understand the working of the materials.
- Wer: Aha.
- Wee: I do understand now how to bend paper, how to bend plastic ---
- Wer: Aha.
- Wee: --- And a --- how to make holes through those materials.
- Wer: Okay, okay. Looking at something like brass, magnesium, would you say you have learnt something --- in --- as to --- compared to their application and their use?
- Wee: Yes --- particularly th -e --- the alloying part of it ---
- Wer: Aha.
- Wee: --- I have learnt of --- how they are produced, their strengths and --- and different types of forces.
- Wer: Okay. Being a woodworker, you appreciate having learnt Material Science?
- Wee: Y--. Although it was inclined more towards metalworkers, but I have learnt a lot and I appreciate it.
- Wer: Okay. Right, can I say now, in your learning of Machine Shop Practice, do you have a chance of exhibiting your knowledge of Material Science to your Machine Shop Practice course?
- Wee: A-a--- in many ways, yes a---
- Wer: How so?
- Wee: --- like --- I am looking forward to a situation whereby, when I go back to my station, I --- I will have to use the knowledge gained in Material Science and Machine Shop Practice. I am going to have my junior classes working on 'card' before they proceed on working on wood because I feel, the costs --- it's more cost effective really to work with card than actually on wood.
- Wer: But my --- my question sir is, do you have a way, as you are doing your Machine Shop Practice now ---? Do you have a chance of applying that --- that --- what you learnt last semester to what you are doing now I---n --- in Machine Shop Practice?
- Wee: In Machine Shop Practice? ---
- Wer: Do you have a chance of ---
- Wee: ---o f --- of applying that knowledge?
- Wer: Ya-a.
- Wee: E-e ---, I think the chance is there --- the chance is there, now that I am enlightened, I have a choice on what --- on what to do. I --- I can make up mind as things unfold.
- Wer: Could you then say, there --- you experiencing some problems maybe in you application of this knowledge to the Machine Shop Practice?
- Wee: E---e --- no, I am not experiencing problems as such, but I want to say, e-e ---, in Machine Shop Practice --- at --- currently, we are working on card and learning how to paint, say, when we are working with children's and the like --- we --- we use card for Machine Shop Practice and use paint and other materials which are possibly non-toxic --- and that knowledge come from the knowledge of Material Science.
- Wer: Aha --- Material Science --- okay. E-e --- well, this one I wanted to ask you and say, 'Would you then be able to assist you're your pupils ---, let's you go back to your station?' And we --- you have already discussed that. But, I am saying now, 'When you are back at school, you have attained your degree, do ---do you see yourself having problems in trying to implement what you learnt in Material Science?
- Wee: A-a ---not at all, because as I am looking at things like this in Bulawayo for example where I am stationed, a-a --- I am seeing myself now being able to take my students for field trips where they will be able to really see --- e--- these materials being manufactured. I can take the --- to ---, I can take them to --- to people who, --- who are manufacturing dishes --- you know they are in the plastic business --- and things like that. That's what I would them to see.
- Wer: Okay. So, we can say Material Science has been like a driving force ---
- Wee: That's true.
- Wer: that has made you feel energetic? ---
- Wee: E--- energetic ya-a.
- Wer: --- and well, just for interest's sake, 'Do you think Material Science enters the lives of in --- individuals, regardless of even saying school setting or when you are looking at the community, do you see yourself ---, maybe trying to enlighten the community?
- Wee: Yes. A-a at the present moment, what happening is that, if you --- at a-a --- the --- the --- if you look at the --- the utensils that are in use, ---
- Wer; Aha.
- Wee: --- most of them are actually eventually becoming plastic. I think, it is important for the community to understand the transition that is going on and I think we can only e-e --- make them understand that --- e- that transition through teaching kids about Material Science.
- Wer: Since they belong to the community?
- Wee: Yes.
- Wer: Okay sir --- e --- my pleasure, I --- I thank you very much for your time. And we hope that in future maybe we'll be able to come cover to your schools and discover what you are doing. Yes, I thank you very much sir.
- Wee: You are most welcome.
- Wer: Thank you.

**Appendix 10:** Demographic data matrix from Cohort '1' Interviews

| Int. | Sex | Age | College | Period | Qual. | Subj. | Teach | Exp. | Sch. District | Loc. | B.Ed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Male | | BTTC | 1983-86 | Dip.Ed. | WW | WW | 16yrs. | Midlands | Urban | W.T&D |
| 2 | Male | | BTTC | | Dip.Ed. | WW&Math | WW | !5yrs. | Mash.West | P/Urban | W.T&D |
| 3 | Male | | BTTC | 1996-99 | Dip.Ed. | WW | WW | 3yrs. | Mash. Cent. | P/Urban | W.T&D |
| 4 | Male | | BTTC | 1989-91 | Cert.Ed | WW&Geo. | Geo. | 12yrs. | Mash.West | P/Urban | W.T&D |
| 5 | Male | 30yrs | BTTC | 4yrs. | Cert.Ed | MW | MW | | Bulawayo | Urban | M.T&D |
| 6 | Male | | BTTC | 4yrs. | Dip.Ed. | MW | MW | 3yrs. | Mash.West | P/Urban | M.T&D |
| 7 | Male | 34yrs | BTTC | 1991-93 | Cert.Ed | WW | WW | 11yrs. | Masvingo | Rural | W.T&D |
| 8 | Male | | BTTC | 3yrs | Dip.Ed. | WW&Math | WW | 12yrs. | Midlands | Rural | W.T&D |
| 9 | Male | | BTTC | 2000-02 | Dip.Ed. | WW | WW&Geo | 3yrs. | Harare | Urban | W.T&D |
| 10 | Male | | CTTC | 4yrs. | Dip.Ed. | Fabric.Eng. | MW | 4yrs. | Mash.Cent. | P/Urban | M.T&D |
| 11 | Male | | BTTC | 4yrs. | Dip.Ed. | WW | WW&Math | 6yrs. | Chipinge | Rural | W.T&D |
| 12 | Fem. | 27 | BTTC | 4yrs. | Dip.Ed. | WW | WW | 4yrs. | Harare | Urban | W.T&D |
| 13 | Male | 30 | BTTC | 4yrs. | Dip.Ed. | WW | WW | 3yrs. | Midlands | Rural | W.T&D |
| 14 | Male | | BTTC | 4yrs. | Dip.Ed. | MW | MW&Scie. | 3yrs. | Mash.West | Urban | M.T&D |
| 15 | Male | | CTTC | 3yrs. | Dip.Ed. | Fabric.Eng. | MW | 2yrs. | Mash.Cent. | Urban | M.T&D |
| 16 | Male | | BTTC | 4yrs. | Dip.Ed. | MW | MW | 5yrs. | Mash.Cent. | Urban | M.T&D |
| 17 | Male | | GTC | 1977-79 | Cert.Ed | WW&MW | WW | 24yrs. | Bulawayo | Urban | W.T&D |
| 18 | Male | 39 | BTTC | 1986-90 | Cert.Ed | MW | MW | 14yrs | Chiredzi | P/Urban | M.T&D |

**<u>Appendix 11</u>:** Relationship between MS and MSP in learning matrix (Question 1 of Cohort 1 Interview guide)

| Int. | Related? - Nature of relationship? |
|---|---|
| 1 | Yaa-a, a-applying what we learnt in MS, in MSP is that we integrate what we learnt in Machine Shop --- the relationship mainly, is in the use of materials. E-e we now understand basic materials and what you are supposed to use if you are making a component that probably you can say is going to absorb heat, for example. So you need to know the composition of that materials? |
| 2 | The relationship is in the selection of materials in the projects we are designing. We designed e-e, an artefact for farmers. Yes---for shelling ground-nuts and maize. We were supposed to put into consideration, selection of the materials, depending on where those materials are to used. They are not supposed to rust, and all that knowledge was coming from Material Science. |
| 4 | To me, I can say e-e-it has a lot of benefits because I also did my research project concerning MS. The topic was, 'A study of student teachers -e-e- using MS --- in designing'. What I discovered was that all the students pointed out that "My perception, as a teacher was also correct --- kuti (Shona for *'that'*)--they indicated that Material Science is a very vital component in technical subjects, especially when you are concentrating on this D&T issue--, there is no way you can--introduce a program which --- does not complement the material-e-choice that you have made. Ya-a--you are an incomplete designer--if you don't have knowledge of MS. |
| 7 | Well--(clearing throat)---. Well the relationship particularly relates to the choice of materials in the design situations which we are given. Before we came here, we had no knowledge about materials. So, the content that we learnt last semester is what we are using to apply when it comes to choice of materials for particular designs. We actually use the knowledge that we obtained from MS, the materials such as plastics for example, metals such as mild steel, brass, are the ones that we are currently using. This knowledge was obtained from the lessons on MS. |
| 8 | Okay --what I can say is the relationship is that, before we did Material Science, e-e, when we think of materials, we were only concentrating on wood since we had specialized in wood-e-Woodwork._But now, after doing Material Science, we realize that,-eh-as you design, you are broadened to variety--to a variety of materials -e-looking at their weaknesses, their strengths and so on._So, we're no longer confined to wood. We can think of plastics, ceramics, metal and rubber for example. |
| 9 | Yes, there is a very big relationship._E-e, you find in this semester, we made--we were supposed to design, actually we designed a project for new farmers. Myself, I designed an orange sorter, --- a project that sorts or grades oranges. So, since oranges produce liquids and are acidic, the materials I consider on my--investigations, were supposed to be those materials that do not corrode. |
| 11 | Yes there is a relationship. When you are selecting materials for the artifacts you have designed --- sure. Normally--basically--from what I was saying,--when selecting the material and determining what material is strong, I think properties--from the properties of different materials, I think--I think it enabled me to determine which one is the most suitable. |
| 12 | Yes, to a certain extent. Because in MS last semester, we learnt about the different materials that you can use when you are making artifacts and this time we're designing different artifacts and considering the materials that we learnt about last semester. We are now applying that knowledge to the different a-a- toys and Agricultural equipment. |
| 14 | Ya-a, theoretically, there seems to be quite a relationship, but in terms of what we are doing right now, maybe resources are not that easily available, but I can say, there is a link because we now know that whenever you are designing say, a structure you actually know the kind of materials that you need to use here and there even though at times we really find it difficult to acquire some of those things, but knowledge is available and we exactly know the type of material to use. |
| 16 | Yes, there is a link-e-because currently, we---are--are doing some projects. We are doing the second project this semester and we have done another one, which was based on farming equipment focusing on the new farmers just resettled by the government. Yes, because we had to design a machine or equipment for the farmers, easy to maintain and also made from locally available materials. |

| | |
|---|---|
| **17** | There is definitely a relationship. We--you see, my--my stay here at the university has made me understand really how to work with materials like ‘card’. I--I will tell you, if you realize the way I do the cutting now--it’s much different from the previous time when I--I started working on card --but, MS is also making me understand the working of materials. |
| **18** | Yes._You see, --- what can I say? --- When we are looking at materials that are used, we need to know the types of materials, their strength and the like. All this is derived from the lessons in Material Science so that each stage we work on has some relevance to the Material Science information that we have learnt. |

**<u>Appendix 12</u>:** Chance(s) to apply MS in MSP matrix (Question 2 of Cohort 1 interview guide)

| **Int.** | **Chance(s)? --- Explanation of nature of application** |
|---|---|
| **2** | Material--. Yes. Like—like right--right now, it's different from what we did last year. Last we were just selecting materials at random. We now know which material should suit such, such a project. E-e--, in the selection of the material which we are using for designing these projects we -can now--, for example, a toy for children-- we now know that the best material you can use is plastic. E-e-we cannot use glass because kids are fond of transferring there and the like, so at least plastic may last on toys and is safe for the kids. |
| **4** | That is quite real, because right now, if you are designing something, first point of all-e-e-you should--you should have in mind is that, there is no way you can design a product without considering material because, by choice of material, you'll be considering things like principles of application, and also you need to know the environmental effects--or even the social effects of the material that you are going to use. So, at the end when end up saying, I am going to design this, you should have considered the material that you have, in terms of strength, weaknesses that it has,--other social environmental issues and at the same time, you also need to know that some materials can be harmful. |
| **5** | Ya-a definitely, because currently we are designing something. So, I am actually not just designing, but I am considering what I learnt in my Material Science in order to choose particular materials. For instance, I wouldn't just choose wood where it's not applicable. I will choose wood for a specific purpose. Or, I wouldn't just pick up and use rubber. I will choose rubber because it's important or it's applicable. And, I wouldn't just choose e-e, maybe metal or mild steel, or anything, but I will have to consider which type of metal do I want? Is it stainless steel, is it mild steel, considering the strength, considering the e-e, machineability and everything like that, durability and ductility, all those e-e, properties. |
| **6** | Definitely yes because, choice of material has improved greatly from the use of just materials. Previously before we were done Material Science, choice of material was very poor. But now, with knowledge that we have in Material Science of -e- behavior of different materials, due to different conditions, we are now--we now use the materials available locally wisely. |
| **7** | Yes. _For instance, the--in the design process, there is a stage after the--the completion of design--you have got to decide on what materials to use in the particular design--._Now, you actually use the knowledge that you obtained from Material Science, the materials such as plastics for example, metals such as mild steel, brass, are the ones that we are currently using. This knowledge was obtained from the lessons on Material Science. |
| **8** | Yes, otherwise our designs were limited by just looking at, a-a - mono-material that's wood on--only._Okay, -e- (clearing throat)--when it comes to the processes which are involved in the construction and the finding of materials,-e-you would realize that, e-e- previously we just used to concentrate on processes, those of Woodwork only. But now, we can--we have learnt about processes--of processes--of processes in metal--different types of metals, their strengths, their capabilities, their densities and all the like. So, we design, we implement that. |
| **9** | Yes--we-e- to some extent. You find we actually do not have the--the real application, but theoretical application because we are supposed to investigate on--on the materials that we are supposed to use when we are doing our designs but actually we make mock-ups. Of course mock-ups are not made out of the real material. So, here we make our mock-ups out of a-a-, thick card. Had it been that we use--we--are supposed to make models, then I would say we are going to apply. |
| **11** | Sure. Normally—basically--from what I was saying,--when selecting the material and determining what material is strong, I think properties—from the properties of different materials, I think--I think it enabled me to determine which one is the most suitable. |
| **13** | Yes—you—you are given that chance._We--we learnt about characteristics of--of materials and as a result, we're applying those characteristics in selecting materials for designing--in our designing course. |
| **14** | Ha-a, of course, you may have brilliant ideas but like I have said, some materials are hard to come by. Like we are given design situations and the materials that we are supplied with are usually cards, thick cards, which makes very difficult for us to actually use some of the materials that we really require. Besides that you can ---you only need to acquire some of your own material but now it depends on how well connected you can be. Ya-a, to some areas there is concrete evidence because we have managed to produce some of the artifacts using the |

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| | knowledge and the skills that we learnt in MS in applying to MSD that we are currently doing. |
| **17** | In Machine Shop Practice?--Do you have a chance of--of--of applying that knowledge? E-e-, I think the chance is there--the chance is there, now that I am enlightened, I have a choice on what--on what to do. I--I can make up mind as things unfold. |
| **18** | Yes, so many chances. Yes. Well--I want to belief there is some aspect of evidence, especially where you are consulting e-e-engineering textbooks and during situations like, investigations and the like, and then up to stages where you finally choose the appropriate e--model to make. So you find when yo-u-you-you peruse over, you-you-you-you relate to some of the things, which you covered. |

**Appendix 13:** Evidence of MS in practical activities during MSP matrix (Question 3 of Cohort 1 interview guide)

| Int. | Description of evidence |
|---|---|
| **1** | Like right now, in my project, I have applied it in the body of my toy that I am making, e-ee if I was going to realize it, I was going to use aluminium. And from then on the tires, obviously I would need rubber so that at least there is grip. |
| **2** | E-e-, in the selection of the material which we are using for designing these projects we can now, for example, a toy for children--we now know that the best material you can use is plastic. E-e we cannot use glass because kids,--they are fond of transferring there and the like, so at least plastic may last on toys and is safe for the kids. |
| **3** | Because you find e-e-the--, like the projects that we have done so far, right now we are focusing on a toy project for small children. So, you find out that, like the knowledge we got in plastics, that we did last semester, is very beneficial because toys are supposed to be made out of plastics,--now that we know. |
| **5** | Ya-a definitely, because currently we are designing something. I am actually not just designing, but I am considering what I learnt in MS --- to choose particular materials. For instance, I wouldn't just choose wood where it's not applicable. And, I wouldn't just choose e-e, mild steel, or anything, but I will have to consider which type of metal I want. Is it stainless steel, is it mild steel, considering the strength, considering the e-e, machineability and everything like that, durability and ductility, all those e-e, properties. |
| **6** | Yes, ---it's evidenced by--by the quality of the projects that we are doing, that the materials chosen are now much more--e-e, actually I could say the materials--material that we are using now is much more--. What can I say? E-e-, to choose from--the background -e-e-. Yes,-e- I'll a-a-that' just about it. E-e-, I should say of course, the subject has given us insight into the different materials --but-e-e-, I would--I would appreciate if, maybe we would make a better project--rather than a small toy --- using the actual materials. |
| **8** | Okay,-e-(clearing throat)--when it comes to the processes which are involved in the construction and the finding of materials,-e-you would realize that, e-e- previously we just used to concentrate on processes, those of Woodwork only. But now, we can--we have learnt about processes--of processes--of processes in metal--different types of metals, their strengths, their capabilities, their densities and all the like. So, we design, we implement that. |
| **11** | Normally, we used to focus on wood alone. But, when designing different materials you find that different material are used. So, that subject gave us an idea of how different materials are used by giving an idea about their properties. |
| **12** | Yes. Presently there is, unlike when we started --- when we were doing Part 1 of this Design, last year, some of us didn't any --- know anything about some of these materials, especially metals and after --- when --- after the Materials Science that we learnt more about metals, concrete, plastics and we are now applying that knowledge. |
| **14** | Ya-a, to some areas there is concrete evidence because we have managed to produce some of the artifacts using the knowledge and the skills that we learnt in Material Science in applying to Machine Shop Design that we are currently doing. There is evidence, of course like I would keep on mentioning, in some areas you really face difficulties but, there is evidence --- concrete evidence relating to what we have already made. |
| **15** | Y-e-s-yes of course, I think so. There should be evidence that one has done MS because--of course--our selection, our---our choice of materials right now is based on the knowledge that we got. A layman of course from the street cannot be in a position to choose the appropriate materials I a given situation of need. For instance, if you are looking at--we have a situation where we are making--like in our case we are making a toy. |
| **17** | There is ---there is--because we--you see my stay here at college, at the university has made me understand really how to work with materials. I will tell you, if you realize the way I do the cutting now--it's much different from the previous time when I---I started working on card—but, MS is also making me understand the working of the materials. |
| **18** | Well --I want to believe there is some aspect of evidence, especially where you are consulting engineering textbooks and during situations like, investigations and the like, and then up to stages where you finally choose the appropriate model to make. So you find when yo-u -you peruse over, you—you relate to some of the things, |

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| | which you covered. |

**Appendix 14:** Problem(s) encountered in efforts to apply MS in MSP matrix (Question 4 of Cohort 1 interview guide)

| Int. | Problem(s) ---YES or NO? ---and nature of problems? |
|---|---|
| 1 | **YES:** _As of now, you know--, some of the materials that we learnt about, yes although we would have wanted to use them very much, you find that they are not available on the market. Yes. E-e, the prices are quite exorbitant._That's the major factor. And two, if they are available, they are only sold in large quantities so you can't buy a small amount for making a toy. |
| 2 | **NO:** _Ha-a-I- we haven't--I haven't had any problems so far. |
| 3 | Well, yes e-e, because you find out that the Machine Shop that we are doing right now, e-e- sometimes we are required to make e-e, mock-ups e-e, probably out of thick card._So, you find out that we cannot sometimes implement some of the materials that we would really want to implement; suppose for example, we need to implement rubber on probably the wheels of e-e, toy. But, we cannot do that because we do not have access to material, so we end up using thick card only. |
| 4 | **YES:** _A-ha--A-a--the problem that I might say,-e-e-. It might not really be a problem, but we are saying, the resources that we are given-e-e-the restriction that we have is that we are only supplied with 'card'. So at the end of the day, we are saying 'card' might not be the correct material from the word 'GO'--those mock-ups can not even really fully satisfy my designer intentions, in the sense that I am in a position to use the right material that I want--maybe this is because of problems associated with the availability of materials. |
| 5 | **YES:** _Ya-a, of course here and there, because Material Science was quite --- quite -e- an eye opener. There is so much depth in that course to the extent that sometimes e-e, it becomes difficult to really, e-e choose a material because you will be knowing at the back of your mind that this material has got some qualities that if I use, it's not proper. So now, I can not just pick any material. |
| 6 | **YES:** _E-e-, I should say of course, the subject has--has given us insight into the different materials available--but-e-e -, I would--I would appreciate if, maybe we would make a better project-- rather than a small toy to--, using the different material available, I would prefer a situation whereby we go into the workshop and manufacture something much bigger using maybe materials that we might not use when making these toys._In terms of realization--yes-- rather than just making a small toy, because you would concentrate on very few materials and you would not, maybe, include some of the materials that you would have learnt. |
| 7 | **NO:** _E-e, I wouldn't say, there are any problems. |
| 8 | **NO:** _Ha-a currently, we can't say, there are, any problems since we are concentrating on mock-ups. But, given the chance, we had to make prototypes, probably we -e-e-have to experience some problems. |
| 9 | **NO:** _No—there are no problems. |
| 10 | **NO:** _Not at all. |
| 11 | **NO:** _In fact, it by --- because we learnt about ---e--- different properties of different materials, so it simplified the problem, which we used to have. Normally, we used to focus on wood alone. But, when designing different materials you find that different material are used. So, that subject gave us an idea of how different materials are used by giving an idea about their properties. |
| 12 | **NO:** _No --- no --- in terms of the materials, we are not having any problems. Ya-a, because we are actually considering what we learnt last semester. So actually, we are enlightened. |
| 13 | **YES:** _Ya-a, if the course--that of MS was going to be accompanied by the practical aspect, then it was going to be a bit easier for us to make use of the--what do you call it?--Material that we learnt in MS in relation to wood processing and MSP. |
| 14 | **NO:** _Ha-a--not really. I don't think there are any problems. Because always applying--knowing when and where to use the material. And much has been covered. |
| 15 | **NO:** _ No--not--because-e-e-basi-ba—basically these--these two courses—basically--MSP and MS courses,-e-with Design of course being the practical aspect of the Science course we have talked about. So, a close link-- |

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| | there is a direct link between MS and Design. |
| **16** | **NO:** _A-a--I can say ‘NO’, because we have enough information such that--we are not finding any difficulties. It’s an easy task because, with all the information that we have, it’s quite adequate for selection. |
| **17** | **NO:** _E-e- no, I am not experiencing problems as such, but I want to say, e-e-, in Machine Shop Practice--at--currently, we are working on card and learning how to paint, say, when we are working with children’s and the like--we--we use card for MSP and use paint and other materials which are possibly non-toxic--and that knowledge come from the knowledge of MS. |
| **18** | **YES:** _Yes of course. Wh-a-t--what—what is inhibiting most of the application is time. _There is very little time. |

**Appendix 15:** Application of MS and MSP in teaching matrix (Question 5 of Cohort 1 interview guide)

| Int. | Will assist pupils? --- YES---YES-BUT or NO --- Explanation of whichever case! |
|---|---|
| 1 | **YES:** _Yes very much, because actually, it applies more in the real world than only in designing in the workshop. So, I think there is need to impart that knowledge to pupils because they are going to face different types of jobs that they are going to do in their lives. |
| 2 | **YES:** _Yes, yes, yes. In fact, I will have to apply that because I will--I will have to make my kids understand why we select materials for different projects and why we should use this and that type of material for this and that type of project. |
| 3 | **YES:** Oh yes, definitely, because I—the--the vast knowledge that we have now in terms of materials, will really enable us to function well--because you find out that the Material Science that we have done will really enable us to teach even some of the subjects that are available in schools, suppose the school can no longer afford to teach Woodwork, to--to offer Woodwork, I mean, then you will--we will be able to function as probably Science teachers because we now have a great knowledge--or even to teach the Materials Science itself. Ya-a, in Wood ya-a, so I can easily take up Metal, I can easily take up Physics or Science. |
| 4 | **YES:** It will be very important because, what we are looking at, in terms of, e-e- of our program, it doesn't restrict us into the classrooms only. You can also even start some clubs in schools--whereby you will be doing some designing--and at the end, you never know, someone might take up that idea and become a--or even an entrepreneur on his own. But, you find that, the basic problem that you face is that, if there is lack of material, you might find that you will only end up having only the basic concepts without the detail. |
| 7 | **YES:** Definitely, because you--before coming here, the choice of material was based on intuitive knowledge, after perhaps researching about materials and in most cases, the materials that we used were not suitable for a particular project. Having learnt MS from this college, I think I will be in a better position to advise students to choose the appropriate materials for a particular situation. |
| 8 | **YES:** Ya-a, yes I--I see myself -e-assisting a lot in implementing the knowledge learnt from Material Science--because -e- since I have now a broader knowledge on materials._Okay. Even if, --when I am teaching my--pupils about the design process, I'm no longer going to teach them so that they will be confined on wood only. I will try to highlight them to-e-try to look for different types of materials, indicating some limitations, advantages and all the like. |
| 10 | **YES-BUT:** Ya-a, if circumstances permit because you find that, in as much as you would want to do certain things or introduce certain issues, there may not be--rather the environment may not be appropriate for that. |
| 11 | **YES-BUT:** In general, I think in general--in general life, it's more applicable,--it's more applicable in general life. The problem in school normally,--normally it depend on the availability of various factors, like equipment and the like. In applying wood and other materials in schools, there is a limiting factor, but in general life, it is going to be easier talking to people about the importance of materials. But now, at school level, there is limit, because normally at school, you are focusing on a syllabus. |
| 12 | **YES-BUT:** Ya-a, to a certain extent. Some of these things you can apply because you see, I am within Wood Technology and mostly, we will be dealing with wood and most of the things that we learnt from MS they are basically to do with metals and you know, those syllabus at school, they don't have much--it's only when you talk about things like fittings, then you talk about these metals and plastic. You just talk about it in passing. But basically in wood, what I learnt about wood will definitely apply. |
| 13 | **YES-BUT:** Yes. I'll make use of Material Science in designing aspects. The pupils will make use of those materials in their designing aspects especially the projects in their 'O' Level course. Yes. To some extent --- I am going to implement some of the concepts. The only hindering factor might be on the resources availability--, given the prevailing economic conditions. |
| 14 | **YES-BUT:** Ha-a, if wishes were horses, I think we'd all be ridding. That's my wish. But like, we know the current situation--the prevailing situations in school cannot--at times does not permit us to do those things--sometimes you appear a bit ambitious here and there and you meet a lot of huddles but given the chance--I wish a-a--I'll go and implement and actually try and invent and actually--maybe sometimes change the materials that |

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| | we have been using and try to introduce some other new materials--- metal has become so expensive. |
| **15** | **YES:** Yes, actually that's--that's the whole idea, of furthering my education later, but the basis definitely is trying to get as much as I can get in college and the--then try to--to impart it to pupils in schools. That's the essence. |
| **16** | **YES:** Definitely. I—like the--in these days, you know, materials are very expensive for our subjects—for technical subjects and most of the times--we have to do without the actual materials and you have to find substitutes. So, with the information from MS, I discovered that we could produce materials from--quite a number of materials--from very simple materials. We can substitute. |
| **18** | **YES-BUT:** here are very slim chances, I don't think back schools, I don't think we'll have adequate time to implement everything that we learnt under MS. |

**<u>Appendix 16</u>:** Anticipated problem(s) trying to implement MS and MSP back in schools matrix (Question 6 of Cohort 1 interview guide)

| Int. | Problem(s)? ---YES? ---NO? | Possible solution(s) in case of problems |
|---|---|---|
| 1 | **NO:** _Yes. E-e, the prices are quite exorbitant. We have never had a problem if you ask for money from our SDA. They have always chipped in if you ask them. There is no problem. | N/A |
| 2 | **YES:** _Yes, there might be problems, especially financial problems where schools might fail to buy some of the material which you want to use for your projects. They might tend to look for cheaper materials. | Financial support, esp. from the ministry, and e-e, the SDA in particular. |
| 3 | **YES:** _Ya-a, to a less extent, because you find out that the Material Science that we have done will really enable us to teach even some of the subjects that are available in schools, suppose the school can no longer afford to teach Woodwork, to--to offer Woodwork, I mean, then you will--we will be able to function as probably Science teachers because we now have a great knowledge--or even to teach the Materials Science itself. | *<u>Note</u>: Possible solution sounds implied in problem as stated i.e. one being flexible in terms of teaching subjects.* |
| 4 | **YES:** E-e, that might depend on one, if you're establishing that club at school, it depends with the approval of the superiors, because most of them, e-e- especially in my case, I have trying to persuade them--, my--my superiors to start this suggestion, but all what they knew is, it involves a lot of money, you need machinery, but anyway you tell them, 'No, it's not a matter of machinery, because you can have only two planes with ten children and you can move on. | *<u>Note</u>: Possible solution implied in problem as stated i.e. starting operations even few tools in order to make a start and move on!* |
| 5 | **YES:** Ya-a, there could be problems in--you know—for me to ex--exactly lay out the Material Science, the way I have been taught here, I probably need e-e to first of all teach pupils about chemistry, especially chemistry itself. Yes. Now, if you find most of these classes that do practical subjects, depending on the school, some schools--, they choose e-e-, they say that e-e, those kids which are not properly –e-, gifted academically, they are the ones that do the practicals. So, it becomes difficult now for me--. It will be difficult for me to teach them the chemistry behind materials because it's just an easy thing. We have to understand the chemistry. Now that these classes are the dull, or let's call them dull students and it becomes difficult for them to capture the stuff. | E-e, I wouldn't suggest. Probably, if I go back to my school, that e-e the - e - practical subjects should not be done by those classes that are considered to be dull, but they should be subjects that should be done even by those intelligent pupils or gifted students --- students, so that when- e-e- when you teach them about chemistry, and material --- the science behind the materials, it won't be difficult, especially those science students. It will be easy to, like if you to be given a science class, I will just run over the chemistry because they know that and when I talk about the Material Science now, it won't be a problem. |
| 6 | **YES:** I'll—I'll definitely implement Material Science, but from my knowledge of the situation in schools, I might face problems in the sense that materials are not usually available. | We would have to do with very little resources available in the school. |
| 7 | **YES:** E-e--as you mentioned, our schools are actually hand-capped by financial, -e- lack of financial resources. So, in most cases, where appropriate, we'll simply -e-teach the concepts theoretically. | Where we can manage we'll just get one or two, depending on the available resourc -e- financial resources. |

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| **8** | **NO:** No problem stated here. | N/A |
| **9** | **YES:** The problem that I can see is actually of acquiring the materials because most of our schools-a-a-even, they cry or they feel they don't have the money to buy even wood, which is the basic material in the department. So you find if you are to ask them to but materials such as glass, oh-oh, -I think I am going to have a mountain of ---. | But, I think I am going to try and convince them that there is dire need to have these materials. |
| **10** | **YES:** E-e- basically, you can't--you might not even have the equipment, you might not even have the resources, say financial resources to get the required materials. To a great extent, yes, there are some problems but basically, here and there, in every--day to day lives—in life, you can apply, but to a great extent you can have problems---. | If you don't have the right platform, then you'll have problems--regardless of how much knowledge you have got problems since change can't be done overnight. It is a process and might need time. (*Rather a comment*). |
| **11** | **YES:** The problem in school normally-- normally it depend on the availability of various factors, like equipment and the like. In applying wood and other materials in schools, there is a limiting factor, but in general life, it is going to be easier talking to people about the importance of materials. But now, at school level, there is limit, because normally at school, you are focusing on a syllabus. So, spending time talking about materials in general, which might not be in the syllabus, when you're after making the pupils pass, there comes a problem. Ya-a, but normally, you explain in passing, but you do not put more attention on things like properties of metal, unless it comes into a design but then it's rare. | No solution suggested |
| **12** | **YES:** Ya-a, in schools, we basically have this shortage of equipment to apply some of these things, but, as for myself, I'll try with limited resources that I have what I can do, I will definitely. | Manage with the little that is there. |
| **13** | **YES:** To some extent --- I am going to implement some of the concepts. The only hindering factor might be on the resources availability, given the prevailing economic conditions. | No solution suggested |
| **14** | **YES:**--the prevailing situations in school cannot--at times does not permit us to do those things--sometimes you appear a bit ambitious here and there and you meet a lot of huddles but given the chance--I wish a-a--I'll go and implement and actually try and invent and actually--maybe sometimes change the materials that we have been using and try to introduce some other new materials that we have learnt here and actually saw becoming of vital importance as --metal has become so expensive in my area so I think plastic and some other , materials that we haven't used before, can be made of use in the--in the schools. | change the materials that we have been using and try to introduce some other new materials that we have learnt here and actually saw becoming of vital importance as--metal has become so expensive in my area so I think plastic and some other materials that we haven't used before, can be made of use in the --in the schools. |
| **15** | **YES:** Well--generally I should say yes, considering the non-availability of-e-resources in the schools and the country right now. Y-Yah-a, actually material--material resources in schools, that's--books—textbooks and--and consumables as well. | They definitely should be an impediment but, -a-a- you should--from the design process we should be in a position probably to improvise and over-come. |
| **16** | **YES:** I--like the--in these days, you know, materials are very expensive for our subjects--for technical subjects and most of the times--we have to do without the actual materials and you have to find substitutes. So, with the information from Material Science, I discovered that we could produce materials from--quite a number of materials--from very simple materials. | We can substitute if you know the properties of the other available materials, which are not currently in use. You will be able to utilize those for the purpose of progress in problem solving. |
| **17** | **NO:** A-a-not at all, because as I am looking at things like this in Bulawayo for example where I am stationed, a-a- I am seeing myself now being able to take my students for field trips where they will be | |

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| | able to really see –e- these materials being manufactured. | N/A |
| **18** | **YES:** At times --. There is very little time. _Back-up textbooks are needed, which not readily available at schools. Inadequate. Because right now, we can see that, some of the textbooks we are making use of are never found in secondary schools. | Now, wh- what is needed is back-up textbooks. |

**Appendix 17:** Demographic data matrix for Cohort 2 Interviews – pre-practical examination

| Int. | Age | Sex | Col. | Period | Qual. | Subj. | Teach | Exp. | Sch.Dist. | Loc. | B.Ed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 30yrs. | Male | CTTC | 4yrs. | Dip.Ed | MW,Math&TG | WW | 2yrs. | Mash.Cent. | Urban | M.T&D |
| **2** | 31yrs. | Male | BTTC | 1994-97 | Dip.Ed | MW | MW | 5yrs. | Mash.Cent. | Urban | M.T&D |
| **3** | 33yrs. | Male | CTTC | 4yrs. | Dip.Ed | MW | MW | 3yrs | Manicaland | Rural | M.T&D |
| **4** | | Male | BTTC | 3yrs. | Dip.Ed | WW&Science | WW | 10yrs. | Mash.Cent. | Rural | W.T&D |
| **5** | 36yrs | Male | BTTC | 3yrs. | Dip.Ed | MW&Geo. | WW | 12yrs | Mash.West | Urban | W.T&D |
| **6** | | Male | BTTC | 4yrs. | Dip.Ed | WW | WW | 3yrs | Inyanga | Rural | W.T&D |
| **7** | 41yrs | Male | BTTC | Missing | Dip.Ed | WW | WW | 15yrs | Manicaland | Urban | W.T&D |
| **8** | 40yrs | Male | BTTC | 1983-86 | Dip.Ed | WW&English | WW | 17yrs | Midlands | Urban | W.T&D |
| **9** | 27yrs | Fem. | BTTC | 1996-99 | Dip.Ed | WW | WW | 3yrs. | Harare | Urban | W.T&D |
| **10** | 40yrs | Male | BTTC | 1984-87 | Dip.Ed | WW&Maths | WW&Math | 15yrs | Badoma | Rural | W.T&D |
| **11** | | Male | BTTC | 4yrs. | Dip.Ed | WW | WW | | Mash.West | Urban | W.T&D |

**Appendix 18:** Level of preparedness matrix (Question 1 of pre-practical examination interviews)

| **Int.** | **Very well prepared** | **Well prepared** | **Fairly well prepared** | **Lowly prepared** | **Not prepared** |
|---|---|---|---|---|---|
| **1** | - | - | X | - | - |
| **2** | X | - | - | - | - |
| **3** | X | - | - | - | - |
| **4** | X | - | - | - | - |
| **5** | - | - | X | - | - |
| **6** | X | - | - | - | - |
| **7** | - | X | - | - | - |
| **8** | X | - | - | - | - |
| **9** | - | X | - | - | - |
| **10** | - | X | - | - | - |
| **11** | - | X | - | - | - |

**<u>Appendix 19</u>:** Reasons (explanations) for thinking as indicated in Appendix 18 matrix

| Int. | Feeling | Extracts of exact words and/or reason(s) in each case |
|---|---|---|
| **1** | Fairly well prepared | Oh y—e—s ---yes. E--- I---I---I---I can say so. Ya-a, --- E --- I think I am prepared --- I think I am prepared. Okay ---, basically in Ma---chi---ne Sh--- Machine Shop Practice, we are looking at --- a designer –e--- the design process itself and a --- a hell lot of things associated with design. And--e--looking --looking at what we have learnt in--e--Material Science there are a numbers of issues that are of great importance in assisting in design for instance, materials, material types, chemical composition, --- e---. That gives us probably--- the ability to---to tell --e--th-e-i-r-- their --- their functionality in different aspects in design. Well, yes, yes --I--I--I ---I--th--e-the-re, there is a –a-a- great --- a great --- a big relationship and e-e-e- of great significance in terms of our design --what we have learnt in Material Science-Ya-a! |
| **2** | Very well prepared | Definitely sir, I think so. E--- I am prepared because looking to previous semester --we had--we did Material Science--and, this one--as far as I can see it's at what has been --at what we have been doing this semester in Machine Shop Practice. It is the core or the base of the problems we are supposed to be solving and we have been solving. |
| **3** | Very well prepared | A—I—I am prepared. I have--. We--we had some prerequ—iste--e--e – courses like -e-e-Material Science, Engineering Science and Physics, as well as --a-a-- Chemistry. Yes. Material Science is very, very important to—to—to—e--the course, which I am to write—e--Yes to--to undertake. |
| **4** | Very well prepared | E---, I am quite prepared. Because we have gone through the processes that are involved in the--in the design process, so I am quite prepared for this examination. |
| **5** | Fairly well prepared | E--- at the mean-time, I can say we are almost prepared since we did a lot of Material Science, a lot Engineering Science and currently according to what we have done, we have made models using card and consideration of the materials is also applying in the Engineering Science we have been taught. So, we are almost there, I can say. |
| **6** | Very well prepared | Ya-a, I am very well prepared for his exam. Well--I feel ecstatic. I want--I just want to get over with it. |
| **7** | Well prepared | Yes. Actually, this --- course is close to what we have been doing in the teaching field. Yes. Yes, because e—a number of things which are required to design and make, you'll be able to use the materials which you've learnt on, or when --- before --- concentrated on designing things --- but now with this knowledge on Material Science, and the course on Design, where you use a variety of materials I have found I --- I find that the courses are linked. Yes.A--I look forward to seeing an examination, which really tests us on things, which we have learnt, the Material Science, --- on different materials. |
| **8** | Very well prepared | Very much. A--well, I think I have done my work very much--I--I have read and I know the content that is actually required. And, through the study of Material Science I think I have actually prepared very well. |
| **9** | Well prepared | Okay. I am prepared for the exam tomorrow through the Material Science we did last semester and the Engineering Science. |
| **10** | Well prepared | Actually, I can say, I am prepared for tomorrow's examination since we have had enough practice for the examination which is going to take place tomorrow. Mmm--- with the knowledge of Material Science, Engineering Science and some pre-requisites in Semester |

| | | |
|---|---|---|
| | | 1, I should think that --- that is enough to keep for the exam tomorrow. |
| **11** | Well prepared | Yes, I can say, yes I am --- I am --- prepared because I have done some reading and so forth; together with Material Science which we have covered. I think I am well prepared for the exam tomorrow. |

**Appendix 20:** Anticipation of MS being reflected in the practical examination matrix (Question 2 of pre-practical examination interviews)

| Int. | Reflected? - Yes – (In what form?) | No – (Reason (s)?) |
|---|---|---|
| 1 | Okay --, basically in Ma—chi—ne --- Machine Shop Practice, we are looking at—a designer –e---the design process itself and a –a-- lot of things associated with design. And -e -looking - looking at what we have learnt in --e-- Material Science there are a numbers of issues that are of great importance in assisting in design for instance, materials, material types, chemical composition, -- e--. That gives us probably--- the ability to tell --- th-e-i-r--- their --- their functionality in different aspects ---. Well, yes, yes --I --I --th---e-the-re, there is a -a-a- great - a great -- a big relationship and e- e - e - of great significance in terms of our design - what we have learnt in Material Science -Ya-a! | N/A |
| 3 | Ye---, Yes. Material Science is very, very important to ---to--- to --- e--- the course, which I am to write --- e --- Yes to --- to undertake. It --- it --- it gives a background to --- of ---e--- background knowledge --- about the ---e --- course, which I am to undertake. For example, we ---we --- we, in Material Science we did e --- types of material, their strengths, --- and their properties. So, what I'll be doing now is --- applying the knowledge, choosing material, --- the right material for the --- chosen --- e--- design ---and also --- suitable strength as well as its qualities and properties. | N/A |
| 5 | We can safely say so, but in my own opinion, we would have wanted to do more in the sense of using real material, --- rather than the card we are using right now. In real life situations, we would need to see the effect of these materials that we use so that we end up coming up with the real design rather the mock-ups that we are having right now. According to this exam, -- since we also doing mock-ups, I think it will be applicable but I am talking of real life situations whereby we are saying, we are going out there, maybe someone will continue in the teaching field, but one may have a chance of going into industry. Therefore, we would have wanted also to use--the exposure of using the real material--so that we are well versed with what type of materials required is used for suitable products. | N/A |
| 6 | Machine Shop Practice ---. I think, most of the things, I can put into practice. It's only that some of the materials are hard to come by and experimentation --- part of it is lacking. Ya-a, it's --- it's applicable. Sometimes you apply it unconsciously when you are making your decisions on materials and, the sizes. Sometimes --- on sizes it's very conscious. You'll be applying your Engineering Science, Material Science --- all those aspects come in when making decisions on what to do and how to do it. | N/A |
| 7 | Yes, because e--a number of things which are required to design and make, you'll be able to use the materials which you've learnt on, or when--before--concentrated on designing things--but now with this knowledge on Material Science, and the course on Design, where you use a variety of materials I have found I--I find that the courses are linked. I look forward to seeing an examination, which really tests us on things, which we have learnt, the Material Science, -- on different materials. So, I am sure, it's going to be applicable. | N/A |
| 8 | A---, well ---. There isn't much of a relationship because right now, when we looked at Machine Shop Practice, we actually thought we were going to have hands on experience by working right on the machines and doing practical work. A---, well, you can say partially, because mainly we are going to use card and then if ever we are going to be asked to come up with a design, the design actually goes up to the evaluation of model. There is no realization. So, the application of Material Science, yes to an extent, but not much--because in the end, we don't realize anything except for a mock-up and so it doesn't give us much exposure. Yes--I think there is --- there is need for realization to be done because, we can make designs that do not function in reality. So, if we actually come up with a realization, I think we'll be able to actually say, we have learnt this and this works and that doesn't work. | <u>Wer</u>: --So, you think there is nothing like that?<br><br><u>Wee</u>: No --- not at all! |
| 9 | To a certain extent, it will be reflective because some of the things that we did in Material Science we are not actually applying them because we don't--they say there isn't any material for us to have the hands on experience on the materials--To a certain extent as I have said because we only--make models. We don't do the realization part of the exam. Yes. I think in | |

| | | |
|---|---|---|
| | Machine Shop, they should try by all means to makes us at least have the hands on experience of the items that we design--that we--that we--e-e--on the item that we practice, at least we can make some of the real items, because of drawing and models, they don't actually reflect ---. | N/A |
| **11** | I--I should think the relationship was supposed to reflect, but the problem is that we are not doing the actual things because everything we are doing, we are using card. So, we thought at least if we were going to have some practice with the actual materials, we would benefit more. Yes, it will be applicable especially considering that, if we are going to ---, because we are supposed to make a selection of materials which you are going to use in the actual realization and also mechanisms which we are going involve from Engineering Science. Yes, I should think--the workshop part of it. I should think that part should be incorporated because making the models, the mock-up, we are supposed to visit the workshop then we--we use the actual material so that at least we have to apply--Apply what we learnt in Material Science**.** | N/A |

**Appendix 21:** Anticipated degree of usefulness or applicability of MS in the practical examination matrix (Question 3 of pre-practical examination interviews)

| Int. | YES – In what way? | NO – Reason? |
|---|---|---|
| 1 | Ehe (*Shona for yes*) –Yes. --Yes. I think so, because, judging with the nature of the question we--we--we are likely to face in the examinations, --- a situation of questions-- requiring design and stuff like that. Where we --are anticipating probably that we have--e--areas where we will be linking our MS to 'Design'--especially in choice of materials, appropriate use of materials when designing--but probably only to say that --e--wh--a-t -- what has been covered in MS previous semester and --and what we have been facing, looking at --at --e--some of the coursework tasks --- given in design. The-- e- I think there is a great significance and it is of importance what we are, ---. MS because we have learnt a lot in MS and we are using it-- trying to solve some of the tasks in design. So-- so, I think it's a well thought out course. | N/A |
| 2 | Very much so! E--, because there are concepts we are supposed to consider when designing articles and these concepts we have learnt about them in MS. We are supposed to know the structures of the materials, their compositions, e--and various types which can be used as substitutes to the--, materials which can replace each other when you cannot have the ones you want. E--, what I can only say is that the--its relevance as -- even stressed by our lecturer in charge for MSP-- Mr. Gweru--'Please make sure that you consider what you learnt in MS for the exam ---'. This shows that MS is relevant for the MSP examination. | N/A |
| 4 | Yes, it comes in because there is one aspect which -- we can say there are several aspects that we find in --in the design process, like --the research part of it, whereby you're looking at the types of materials that are required in, let's say you are given a group, you have to look at the types of materials that are required. I think that aspect is covered in MS ---. All those aspects are covered in MS, so I think MS is quite important in design. E--, it is-- it is quite applicable. E--actually, as I have -e- already elaborated, you find that, there are certain aspects that you find in --MSP that we will have to-- which we must have some knowledge of. | N/A |
| 5 | We can safely say so, but in my own opinion, we would have wanted to do more in the sense of using the real material that we are going to use, rather than the card that we are using right now because we are saying, in real life situations, we would need to see the effect of these materials that we use so that we end up coming up with the real design rather the mock-ups that we are having right now. According to this exam. Since we also doing mock-ups, I think it will be applicable but I am talking of real life situations whereby we are saying, we are going out there, maybe someone will continue in the teaching field, but one may have a chance of going into industry. Therefore, we would have wanted also to use-- the exposure of using the real material. | N/A |
| 6 | MSP --. I think, most of the things, I can put into practice. It's only that some of the materials are hard to come by and experimentation—part of it is lacking. Ya-a, it's—it's applicable. | N/A |
| 8 | Ya-a. We're actually advocating for more hands on experience because we need that workshop experience, because some of us might not be--might have been trained in the actual handling of machines. So, we need the actual handling of machines then coming up with the realization of what we'll have designed -- we are going to use card and then if ever we are going to be asked to come up with a design, the design actually goes up to the evaluation of model. There is no realization. So, the application of MS, yes to an extent, but not much.Yes, definitely, because in the end, we don't realize anything except for a mock-up and so it doesn't give us much exposure. I think there is--there is need for realization to be done because, we can make designs that do not function in reality. | N/A |
| 9 | Yes. I think in MS, they should try by all means to makes us at least have the hands on experience of the items that we design-- that we-- that we--e-e--on the item that we practice, at least we can make some of the real items. | N/A |
| | I—I should think the relationship was supposed to reflect, but the problem is that we are not doing the actual things because everything we are doing, we are using card. So, we thought at least if we were going to have some practice with the actual materials, we would benefit | |

| | | |
|---|---|---|
| **10** | more. Yes, it will be applicable especially considering that, if we are going to--, because we are supposed to make a selection of materials --- we are going involve Engineering Science. Yes, I should think--the workshop part of it. | N/A |

**<u>Appendix 22</u>:** Level of satisfaction with performance in the examination matrix (Question 1 of post-practical examination interviews)

| Int. | Very satisfied | Satisfied | Fairly satisfied | Not quite | Not at all |
|---|---|---|---|---|---|
| **1** | X | - | - | - | - |
| **2** | - | X | - | - | - |
| **3** | X | - | - | - | - |
| **4** | - | X | - | - | - |
| **5** | X | - | - | - | - |
| **6** | X | - | - | - | - |
| **7** | - | X | - | - | - |
| **8** | - | X | - | - | - |
| **9** | X | - | - | - | - |
| **10** | X | - | - | - | - |
| **11** | - | X | - | - | - |

**<u>Appendix 23</u>:** Level of preparation for the examination matrix (Question 2 of post-practical examination interviews)

| Int. | Very well prepared | Well prepared | Fairly well prepared | Lowly prepared | Not prepared |
|---|---|---|---|---|---|
| **1** | X | - | - | - | - |
| **2** | X | - | - | - | - |
| **3** | X | - | - | - | - |
| **4** | - | X | - | - | - |
| **5** | X | - | - | - | - |
| **6** | X | - | - | - | - |
| **7** | - | X | - | - | - |
| **8** | X | - | - | - | - |
| **9** | X | - | - | - | - |
| **10** | - | X | - | - | - |
| **11** | X | - | - | - | - |

**Appendix 24:** Reflectivity between MS and MSP during the examination matrix (Question 3 of post-practical examination interviews)

| Int. | YES – In what way? | No – Reason? |
|---|---|---|
| 1 | All right, e--we have written our examination on the Machine Shop Practice and Design and we found out that--e--for you to be able to tackle th--e, such a test, you would need great knowledge about Material Science. So, I think this course of Material Science was very useful and it encouraged us and developed us a lot in accomplishing our examination. | N/A |
| 2 | Y--yes—I think--I--I can safely say that--the exam was worth it because -e-we-we--we--we had a lot of depth in terms of information that we covered prior to the examination in terms of Material Science. We had -e-quite a number of aspects and concepts that we used in the exam, which were quite relevant._I think--I think the approach is already--I--I think the approach is good--the approach is --is--is quite good-e-, because it gives you room to-to-to-to work alone--e-of course referring back to the courses that you have covered, particularly Material Science where you have --where you have to--to be in a position to select a number of materials,--a number of concepts that you would use to --to--to come up with better realizations--in the design --in the examination. _Okay e--, the approach that is in place right now, I think it works considering the fact that you need to have a good and sound theoretical background before you move onto the practicals. So you want to take Material Science first before you move onto design and realization--I think the approach is all right. Of course, they can --they can--they can--they can be flexible to adopt other approaches but this one I think it works. | N/A |
| 4 | Like --we did Material Science--especially Material Science. You see, we were doing Material Science and in Machine Shop Practice it's mainly focusing on designing. So, now after doing Material Science, we were now after doing our Material Science, we now have the knowledge on materials of which we are now applying--we now the knowledge on which material is suitable for which job. | N/A |
| 5 | Ya-a--, Machine Shop Practice--it was a good paper actually because we had a chance to apply what we have learnt in Materials Science, especially when we did our market research. We went to St. Giles and we actually had a chance to look at some of the materials, which we learnt about and are actually in use. | N/A |
| 7 | Well, the exam on Machine Shop Practice was quite fair, considering what we had done in Material Science and--Engineering Science. I think it was quite fair. Right--a-a- I'll have to say, from my experience, what we did in Material Science, can be very, very useful to any technologist or designer because we're saying, the moment you know about materials you are very assured of what you are going to do in the practicals, that is in Machine Shop Practice. So--I would like to advocate that wherever there is some theory being learnt concerning materials, there should be--an immediate comprehension on the practical part of it so that students can actually prove to themselves that this is useful and this is not. So I would like to think the idea of bundling them together and running them concurrently, would improve us very much. | N/A |
| 9 | Well, I think it was quite fair, because -e-what we learnt is what we were tested on. E--, obviously Material Science is very important because that is the world we are getting onto, whereby you need to understand about a variety of materials which are coming into use. | N/A |

| | | |
|---|---|---|
| **10** | Yes, the knowledge of Material Science and Engineering Science came in here and there --I think as a designer, the knowledge of Material Science is very good. You must have that knowledge in order to be a good designer. | N/A |

**Appendix 25:** Usefulness or applicability of MS during the examination matrix (Question 4 of post-practical examination interviews)

| Int. | YES – In what way | NO - Reason |
|---|---|---|
| 1 | All right, e--we have written our examination on the Machine Shop Practice and Design and we found out that -e- for you to be able to tackle th--e, such a test, you would need great knowledge about Material Science. So, I think this course of Material Science was very useful and it encouraged us and developed us a lot in accomplishing our examination. Well--, I think--think the structure of the course itself was very good, it was highly organized, that is, the Material Science. It was highly organized and it encouraged us to want to learn more and we actually managed to learn on our own--. | N/A |
| 2 | E--it was okay--it was okay. Judging with the kind of preparations we made--what we have covered before, it was all right. _Y--yes--I think--I--I can safely say that--the exam was worth it because -e-we-we--- we --- we had a lot of depth in terms of information that we covered prior to the examination in terms of Material Science. We had --e-- quite a number of aspects and concepts that we used in the exam, which were quite relevant._E--, it's--. These are concepts--not just concepts--but are actually relevant to the exam. _So you want to take Material Science first before you move onto design and realization. | N/A |
| 3 | E--, I think I have--outlined before that, will be--. I think this has given me an opportunity to--to look into various types of materials, compositions which might give me a wider--choice for selection of materials to use and not restrict us to the workshop only but even going into the community and using available resources. | N/A |
| 4 | Like --- we did Material Science --- especially Material Science. You see, we were doing Material Science and in Machine Shop Practice it's mainly focusing on designing. So, now after doing Material Science, we were now after doing our Material Science, we now have the knowledge on materials of which we are now applying --- we now have the knowledge on which material is suitable for which job. _ Ha-a, I feel that now, I am fully equipped with the knowledge I have learnt from here of which, I feel I will use it, because before we came here we had less knowledge, especially on materials, how to design ---especially even the design --- concepts. We had shallow knowledge on that. But now, we feel, we are now full. | N/A |
| 5 | Ya-a ---, Machine Shop Practice --- it was a good paper actually because we had a chance to apply what we have learnt in Materials Science, especially when we did our market research. We went to St. Giles and we actually had a chance to look at some of the materials, which we learnt about and are actually in use. | N/A |
| 6 | We did Material Science --last--last semester--last semester--last semester--and then we got our Machine--Shop this semester. So already, you can see that--what--what--what we--what we learnt in Material Science we applying this in what--this semester in what—in Machine Shop--which was quite okay--which was excellent--. | N/A |
| 7 | Right--a-a- I'll have to say, from my experience, what we did in Material Science, can be very, very useful to any technologist or designer because we're saying, the moment you know about materials you are very assured of what you are going to do in the practicals, that is in Machine Shop Practice. So --I would like to advocate that wherever there is some theory being learnt concerning materials, there should be--an | N/A |

| | | |
|---|---|---|
| | immediate comprehension on the practical part of it so that students can actually prove to themselves that this is useful and this is not. | |
| **8** | I think there are a number of aspects, which we find in Machine Shop Practice, which --if one had not known in theory about materials--, which we find in Material Science _I think it would be very difficult to come up with a-- projects, let's say, in Machine Shop Practice, just because there are a number of aspects which you have to know before you start your Machine Shop Practice._Yes--yes--because we are saying then in Machine Shop, you are using a variety of materials, so you should know the characteristics of various materials so that you have got a wide choice of materials to choose from and also to choose the appropriate materials for the projects you'll be working on. _Like I have said before, in Machine Shop Practice, we are looking at a number of materials that we use on various projects and in order for us to know the various materials with their properties, characteristics and the like, you need to know--you need to have this Material Science. So I think these two subjects,--what can I say--have, to run concurrently. | N/A |
| **9** | E--, obviously Material Science is very important because that is the world we are getting onto, whereby you need to understand about a variety of materials which are coming into use. _I think there is a lot that we need to understand. | N/A |
| **10** | I think as a designer, the knowledge of Material Science is very good. You must have that knowledge in order to be a good designer. The problem now comes when you have a woodwork background and the Material Science come with less than a quarter of the course outline and the rest is metal related. I think, as you have said earlier if we can combine the Material Science and Machine Shop Practice, and we do the actual practice not just theory so that we learn more about materials and implement the theory, I think that will be useful. | N/A |
| **11** | Yes, we used some of the things we learnt in Material Science, especially the metal.<br><br>The exam was quite challenging. The design task, which we were given, was quite challenging and we really had to think, to come up with a good idea._Oh yes, that knowledge on Material Science was beneficial because as a woodworker, the project I was supposed to do was going to use metal. | N/A |

**Appendix 26:** Excerpt from pre-practical examination interviews (same interviewee as in Appendix 27).

**PRE-PRACTICAL EXAM. INTERVIEW 1**

**1. Demographic Data** (Introduction) **-** Interviewee is MALE.

- Interviewer (Wer): Good morning sir.
- Interviewee (Wee): Good morning. How are you?
- Wer: I am okay. Can you tell me about yourself sir?
- Wee: A – a- well---, as you can see I am a man of course. I ---I --- I am aged 30---
- Wer: Okay.
- Wee: E --- m-y --- my --- my initial teacher training e ---. I did that at Chinhoyi Technical Teachers' College. That was a four year program and, e--- well --- I ---I ---I--- I graduated with a Diploma in Education, Technical Education that is. Well, I --- I --- I --- I specialized in Metalwork, Maths and Technical Graphics. And I have been teaching for 2 years before I came here. Yes, ---. And e --- well --- I have been teaching in Bindura, Bindura Urban at Chipindura High School; it's an urban school in Bindura, in Mashonaland Central Province.
- Wer: Aha.
- Wee: Yes.

**2. Questions** (The interview)

- Wer: Okay, okay. I understand you are about to undertake a practical examination in Machine Shop Practice, ---
- Wee: Aha.
- Wer: --- are you ready for this?
- Wee: Oh y--e—s ---yes. E--- I---I---I---I can say so. Ya-a, --- E --- I think I am prepared --- I think I am prepared
- Wer: What have you so far learnt in Machine Shop Practice that should be reflective of what you learnt in Material Science?
- Wee: Okay ---, basically in Ma---chi---ne Sh--- Machine Shop Practice, we are looking at --- a designer –e--- the design process itself and a --- a hell lot of things associated with design. And ---e --- looking --- looking at what we have learnt in ---e--- Material Science there are a numbers of issues that are of great importance in assisting in design for instance, materials, material types, chemical composition, --- e---. That gives us probably--- the ability to---to tell ---e--- th-e-i-r--- their --- their functionality in different aspects in design.
- Wer: Okay. Do you anticipate this relationship in the oncoming practical examination?
- Wee: Well, yes, yes --- I---I---I ---I ---th---e-the-re, there is a –a-a- great --- a great --- a big relationship and e--- e --- e --- of great significance in terms of our design --- what we have learnt in Material Science --- Ya-a!
- Wer: Do you see what you learnt in Material Science being useful or applicable during this examination? --- What you learnt in your Material Scie-----.
- Wee: Yeh--- wh-a-t --- what ---what I learnt in Material Science?
- Wer: Ehe (Shona for yes).
- Wee: Yes.
- Wer: Do you see it being applicable, to this examination in Machine Shop Practice?
- Wee: Yes. I think so, because probably, judging with the nature probably of the --- the question we---we---we are likely to face in the examinations, which are usually a situation of questions --- requiring the design and stuff like that. Where we ----are anticipating probably that we have ---e--- areas where we will be linking our Material Science to 'Design' --- especially in terms of choice of materials, appropriate use of materials and whatever when designing.
- Wer: Okay, is there anything you thing might be of value or importance to us concerning this Material Science as regards to Machine Shop Practice --- that, you think has been left out during this interview ---,
- Wee: E--- e --- no ---
- Wer: --- that you would like to highlight --- maybe?
- Wee: --- but probably only to --- to say that ---e--- wh---a-t --- what ---what has been covered in Material Science in the previous semester and --- and --- and what we have been facing, probably looking at --- at --- e--- some of the coursework tasks that we were given in design. The --- e- I think there is a great significance and it is greatly --- of great importance what we are ---, Material Science because we have learnt a lot in Material Science and we are using it in ---in trying to solve some of the tasks that we were given in design. So --- so, I think --- I think it's a well thought out course and very helpful in terms of Machine Shop Practice.
- Wer: I thank you for your time.
- Wee: You are welcome.

**Appendix 27:** Excerpt from post-practical examination interviews (same interviewee as in Appendix 26)

**POST- EXAM. INTERVIEW 1**

**1. Demographic Data** (Introduction) **-** Interviewee is MALE.

- Interviewer (Wer): Good morning sir.
- Interviewee (Wee): Hello sir. How are you?

**2. Questions** (The interview)

- Wer: I understand you have finished your --- Machine Shop Practice examination.
- Wee: Yes.
- Wer: So now we are undertaking the post-test so that you can give us your views.
- Wee: Okay.
- Wer: Can you please go ahead?
- Wee: All right, e--- we have written our examination on the Machine Shop Practice and Design and we found out that --- e--- for you to be able to tackle th ---e, such a test, you would need great knowledge about Material Science. So, I think this course of Material Science was very useful and it encouraged us and developed us a lot in accomplishing our examination.
- Wer: Do you feel that there are any changes that have to be implemented in the method of examining, like --- in the Machine Shop Practice?
- Wee: Well e---, not really, because you find out that e--- with --- the structure of the exam itself, would allow us to explore on a number of materials because of the time frame --- that is the duration of the examination. So, you ---, we actually managed to explore on quite a number of materials and that helped us to come up with quite good realizations.
- Wer: So generally, the feeling is that you are satisfied with what you were taught in Material Science and Machine Shop Practice and Design, resulting in the examination in which you have done well?
- Wee: Yes.
- Wer: Okay. So, are we safe to say that you're somebody who is now well equipped to go and face the community and let's say, working for the country?
- Wee: Well --- yes, most definitely because I think the knowledge that we have right now will actually enable us to make a wide variety of ---of artifacts using various materials.
- Wer: So, you don't have anything to ---
- Wee: To, ---?
- Wer: --- add perhaps regarding the examination maybe relating to Material Science?
- Wee: Well ---, I think --- think the structure of the course itself was very good, it was highly organized, that is, the Material Science. It was highly organized and it encouraged us to want to learn more and we actually managed to learn on our own ---.
- Wer: Okay.
- Wee: --- some of the concepts.
- Wer: Okay --- like when it came to using some of those things like the modules and similar items?
- Wee: Yes.
- Wer: I understand you did quite a lot in the modules?
- Wee: Ya-a, it was quite interesting.
- Wer: Okay.
- Wee: Yes. So, I would actually encourage the lecturer to keep up the --- the approach --- or --- that he used on us.
- Wer: Okay. I---I thank you very much for the time.
- Wee: Thank you sir.

**Appendix 28**: An excerpt of the folio analysis schedule showing the amount of Material Science implied in the various sections of the design folio (Note: Only folios 9 to 36 are represented here. The first 8 have been presented in Figure 3.17 in Chapter 3 together with the relevant explanations)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total Scores |
|---|---|---|---|---|---|---|---|---|
| 9 | | √√ | | | | √√√√√ | √√√√√√ | 13 |
| 10 | | √√√√√ | √√√√√√√ | | √ | √√√√√ | √√√√√√√√√√ | 28 |
| 11 | | √√√ | √ | | √√ | √√√√ | √√√√√√√ | 17 |
| 12 | | √√√√ | √√√ | | √√ | √√√√ | √√√ | 16 |
| 13 | | √√√ | | | √√√√√ | √√√√√ | √√√√√ | 18 |
| 14 | | √√√√√ | | √ | √ | √√√√ | √√√√√√√ | 18 |
| 15 | | √√√√ | | | √√√ | √√√ | √√√√ | 14 |
| 16 | | √ | √√ | | | √√√√√√ | √√√√√√√ | 16 |
| 17 | | √ | √√√√√ | | √√√√ | √√√√√ | √√√ | 18 |
| 18 | | | √√√√√ | √ | √√√√√√ | √√√ | √√√√√√ | 21 |
| 19 | | √√√√√√√ | √ | √ | √√√√√√√ | √√√√ | √√√√ | 24 |
| 20 | | √√√√√ | √√√√ | √√√√ | | √√√√√√√ | √√√√√ | 25 |
| 21 | √ | √√ | √√√√√√√√√√ | | √√√√√ | √√√ | √√√ | 24 |
| 22 | | √√ | √√√√√√√√√ | | √√√ | √√√ | √√√ | 20 |
| 23 | | √√√√ | √√√√ | | | √√√√√ | √√√ | 16 |
| 24 | | | | | √ | √√√√√√ | √√√ | 10 |
| 25 | √ | √ | | | √ | √√√√√ | √√ | 10 |
| 26 | | √√√√ | √√√√√√√√√√ | | √√√√ | √√√√√√√√ | √√√√√√√ | 33 |
| 27 | | √√√√ | √√ | | √ | √√√√√√√√ | √ | 16 |
| 28 | | √√√ | √√√√√√√ | √√√√√√ | √√√√√ | √√√√√√√√ | √√√√√ | 34 |
| 29 | | √√ | | | √ | √√√√√√√√√ | √√√ | 15 |
| 30 | | √√√ | | | √ | √√√√√√√√√ | √√√√ | 17 |
| 31 | | √√ | √√ | | √ | √√√ | √√√√√√√ | 15 |
| 32 | | √√√√ | √√√√√√√√√ | | √√√√√√ | √√√√ | √√√√√√ | 29 |
| 33 | | √√√ | √√√√√√√ | | √√√√√√√ | √√√√√ | √√√√√√√√√√√ | 33 |
| 34 | | √√√ | √√√√√√√ | | √ | √√√√√√√√ | √√ | 21 |
| 35 | √ | √√√√ | √√√ | | √√√√√ | √√√ | √√√√√√√ | 23 |
| 36 | √√ | √√√√ | | | √√√√√√√√√ | √√√√√√ | √√√ | 24 |
| | 6 | 95 | 127 | 26 | 101 | 189 | 188 | |

**Appendix 29**: The final examination drawn from module tests 1 and 2

**UNIVERSITY OF ZIMBABWE**
FACULTY OF EDUCATION
**DEPARTMENT OF TECHNICAL EDUCATION**
**BACHELOR OF EDUCATION IN TECHNICAL EDUCATION**
SEMESTER II EXAMINATION
**MATERIAL SCIENCE (TEM/W 207/8)**

**DATE**: June, 2004
**TIME**: 3 hours
**INSTRUCTIONS**: Answer **all** questions (200 marks)

---

**1. Name;**
(a) the two main groups of metals. **(2)**
(b) the bond that occurs between iron and carbon. **(1)**
(c) the three main families into which engineering materials are divided. **(3)**
(d) the most outstanding example of a crystal in which the covalent bond features, mainly involving the carbon atom.
**(1)**
(e) the two bonding mechanisms in ceramic materials. **(2)**
(f) the instrument used to measure high temperatures in matter (e.g. metals). **(1)**
(g) two common methods of converting timber. **(2)**

**2. State;**
(a) the hardest structure in steel. **(1)**
(b) the phase with its structure different from either of the two elements involved in an alloy. **(1)**
(c) the three components in a concrete paste. **(3)**
(d) two soft structures in steel. **(2)**
(e) the atomic numbers of the following elements:
(i) iron **(1)**
(ii) copper **(1)**
(iii) nickel **(1)**
(iv) magnesium **(1)**
(v) carbon **(1)**
(f) the three principal groups into which stainless steel is divided. **(3)**

**3. Give;**
(a) the unit cell of magnesium. **(1)**
(b) Give the other name for an 'elastomer'. **(1)**
(c) two main reasons why the iron-iron carbide diagram is essential to the metallurgist **(2)**
(d) the other name given to the process of "addition polymerization". **(1)**
(e) three categories of synthetic composites. **(3)**
(f) the factor expressing the tendency of an element to donate electrons in a matrix. **(1)**
(g) the formula used to express the coefficient of linear expansion. **(3)**

**4. Specify;**
(a) two main uses of cerium in industrial production. **(2)**
(b) two main factors necessary to understand the structure of a material. **(2)**
(c) the density of magnesium in relationship to that of aluminium. **(1)**
(d) four characteristics of copper. **(4)**
(e) the lattice structure of titanium at room temperature. **(1)**
(f) two major reasons why zinc alloys are suitable candidates for die casting. **(2)**
(h) four types of copolymers. **(4)**
(i) the backbone of plastic like every organic material. **(1)**

(j) the purpose of the radial rays in the tree trunk. **(1)**
(k) where compression and shear properties are important in wood **(1)**
(l) the phase of titanium at room temperature. **(1)**

**5. Highlight;**

(a) the two methods of protecting active elements like magnesium from their tendency to react with the atmosphere.
**(2)**
(b) the three general rules of W. Hume-Rothery one should note in order to form an extensive solid solution (greater than 10 atomic percent soluble). **(3)**
(c) the central fact to polymer structure. **(1)**
(d) one of the main differences between concrete and asphalt. **(1)**
(e) the effect of temperature on the electrical conductivity of ionic materials. **(2)**

**6. Identify;**

(a) the two basically different structural changes possible when a second element is added to an element. **(2)**
(b) the family of engineering materials to which wood belongs. **(1)**
(c) the two main methods of raising the amount of hardness in metal. **(2)**
(d) the force holding electrons in orbit within an atom. **(1)**
(e) the phenomenon within metal grain structures acting as an impediment to slip. **(1)**
(f) the two main groups of plastics. **(2)**
(g) two main mechanisms of polymerization. **(2)**
(h) the main factor on which the process to be used for processing plastic depends. **(1)**
(i) the component that is mixed with paste to form concrete. **(1)**
(j) the feature that is present in the microstructure of softwoods but misses in that of hardwoods. **(1)**
(k) the charge characterizing the proton in the nucleus of an atom. **(1)**
(l) the charge characterizing neutron of an atom. **(1)**
(m) the two factors largely determining the properties of an atom. **(2)**
(n) the four types of backbone structure in polymer formation **(4)**
(o) the three factors that must be considered in any study of heat energy in a body. **(3)**
(p) the type of expansion in solids (e.g. metals). **(1)**



**7. Define the following;**

(a) specific heat. **(2)**
(b) hardness **(2)**
(c) phase. **(2)**
(d) Solid solution. **(2)**
(e) Cold working. **(2)**
(f) composite (relating to materials technology). **(2)**
(g) coefficient of linear expansion (not using formular). **(2)**

**8. Describe;**

(a) the movement of heat between two bodies at different temperatures. **(2)**
(b) the main feature of the covalent bond. **(2)**
(c) the process of die casting. **(2)**
(d) the flexibility concrete offers the designer. **(2)**
(e) the strength qualities of concrete. **(2)**
(f) how annual rings develop in the tree trunk. **(2)**
(g) the two possible situations resulting in atomic energy converting to heat. **(2)**

**9. Explain;**

(a) the phenomenon that keeps the only valence electron in noble metals tightly held in orbit **(4)**
(b) the phenomenon that makes bronze suitable use in the making of bearings. **(4)**

(c) the difference between elastic and plastic strain or deformation. **(4)**
(d) the phenomenon that causes the hardness of a metal component to rise after cold working **(4)**
(e) the phenomenon that causes "HYPEREUTECTOID" steels to harden better than "HYPOEUTECTOID" steels during heat treatment. **(4)**
(f) the effect of temperature on concrete in the process of drying. **(4)**
(g) why steel rather any other metal is used for the reinforcement of concrete. **(4)**
(h) pretensioning in relationship to concrete work. **(4)**
(i) the purpose of adding ground glass to asphalt. **(4)**
(j) why aluminium has such good electrical conductivity. **(4)**
(k) what the addition of heat does to a body of matter. **(4)**
(l) the purpose of a 'terminator' in polymer development. **(4)**
(m) the phenomenon that causes materials (esp. metals) to expand when heated. **(4)**
(n) the fundamental difference between "HYPOEUTECTOID" and "HYPEREUTECTOID" steels **(4)**

**10. With the aid of well labelled sketches, illustrate the following:**
(a) four methods of work hardening metal (name and label the methods appropriately) **(12)**
(b) the three main unit cells that appear in metals. **(6)**
(c) the difference between the interstial and substitutional solid solutions. Indicate examples of the elements involved in each case. **(6)**
(c) the axes used to specify directions in wood. **(3)**

**END OF EXAMINATION; GOOD LUCK!!!**