The Effects of a Dialogical Argumentation and Assessment for Learning Instruction Model (DAAFLIM) on Science Students' Conception of Selected Scientific Topics

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ABSTRACT

The central concern of this study has been to determine the effectiveness or otherwise of a combined Dialogical Argumentation Instructional Method (DAIM) and the Assessment for Learning Model (DAAFLIM) strategies in enhancing Tertiary and Vocational Education and Training (TVET) students' conceptions of selected scientific topics. The extant literature has shown that students often hold other worldviews or funds of knowledge, which might be in conflict with canonical school science. In light of this, DAAFLIM has been chosen for a number of reasons: (1) it has been shown to be effective for revealing students' scientific and alternative worldviews; (2) it provides the learning environment that encourages students to express themselves freely, exchange views with others, reflect on what they have learned, and even to change their minds in the face of stronger arguments; (3) it is compatible with the Curriculum and Assessment Policy Statements (CAPS) curriculum which emphasizes that educators should integrate school science with students' indigenous knowledge as a way to make the former more relevant to their sociocultural environment; (4) assists educators to plan instruction in accordance with the needs of multicultural science classroom; and (5) the combination of classroom discourses with continuous or formative assessment (as exemplified by DAAFLIM), instead of the usual terminal summative assessment, tends to mitigate the fears that students usually associate with assessment. Specifically, a group of TVET students i.e. the Experimental group (E-group) was exposed to DAAFLIM while the other group i.e. the Control group (C-group) was exposed to traditional instruction method (TIM).

In light of this, the following five research questions have been proposed for a closer consideration:

1. What conceptions of selected topics such as; natural phenomena and nature of science (NOS) did E-group and C-group students hold before and after being exposed to DAAFLIM and TIM respectively?

2. Are E-group students' conceptions of the selected topics related to their age, gender or cultural backgrounds?

3. Are the conceptions of the selected science topics: SI-units, Dynamics, Statics and Energy held by the E-group significantly different from those held by the C-group using CAT, TAP and ZPD as units of analysis?

The theoretical framework of this study based on Toulmin's (1985) Argumentation Pattern (TAP), the Ogunniyi's (2007a) Contiguity Argumentation Theory (CAT), and Vygotsky's (1978) social constructivist theory provided analytical lenses to examine how knowledge construction takes place during the pedagogical process, especially during formative assessment activities. A quasi-experimental group design selected for the study involved a mixed-method approach consisting of two intact classes of Engineering Science students. The experimental group received the DAAFLIM intervention and the control group received traditional instructional method (TIM). A lesson observation schedule, Science Achievement Test, open-ended questionnaires and focused group interviews, provided the sources of data for analysis, both qualitatively and quantitatively. The study showed that DAAFLIM improved the conceptions of the experimental group significantly compared to the control group exposed to TIM. Furthermore, most students appeared to hold a dominant western science conception and to suppress their indigenous knowledge worldview at the pre-test. However, at the post-test, although the majority of students still seemed to express a dominant western scientific worldview, there were some apparent cognitive shifts from their suppressed worldview towards a dominant indigenous knowledge worldview.

The socio-cultural and biographical backgrounds of the students did not play significant roles in their performances. However, the integration of engineering science concepts with the students' indigenous knowledge practices may assist curriculum developers and lecturers, to present curriculum content and assessment practices relevant to students' lived-world experiences. Furthermore, the study has demonstrated the value of using the Dialogical Argumentation and Assessment for Learning Instructional Model (DAAFLIM) as a more effective scaffolding pedagogical method to create a teaching and learning discussion space than it is with traditional instruction method (TIM).

Keywords: TVET colleges, dialogical argumentation, formative assessment, assessment for learning, knowledge construction, indigenous knowledge, nature of science, constructivism

DECLARATION

I declare that, “The effects of a Dialogical Argumentation and Assessment for Learning Instruction Model (DAAFLIM) on science students’ conception of selected scientific topics” is my own work and has not been submitted before for any degree or examination in any other university. I acknowledged all the sources used or quoted by providing complete references.

Signed: ……………………………….. August 2021

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It is humane to acknowledge contributions that people made in various and varied ways towards the completion of a milestone in your life. It is also in keeping with human nature to express your profound gratitude to the individuals who wholeheartedly assisted you to accomplish a marvelous achievement. Helping a candidate to complete a thesis is by all standards no small contribution. Therefore, it is prudent to mention those special individuals and to indicate their specific contributions towards the completion of my thesis. Furthermore, it is spiritually gratifying to acknowledge the assistance received.

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GLOSSARY OF TERMS AND OPERATIONAL DEFINITIONS

Assessment	The judgment or appraisal of collected information as evidence of learning and the specific needs of a student (Cooper, 2007).
Assessment activity	An exercise engaging students actively, physically and/ or cognitively, in the assessment process (Chapman & King, 2012).
Assessment for Learning	The educator initiated student-centred instruction, focusing on the students' progress at specific learning instances (Gipps, 1994).
Assessment of Learning	The educator evaluates and judge students work at the end of a unit or period of study (Gipps, 1994).
Assessment skill	The student's ability to use an assessment tool proficiently (Chapman & King, 2012).
Assessment strategy	An approach or tactical procedure used to reach a goal that could be an umbrella for activities, skills or tools (Chapman & King, 2012).
Authentic assessment	A meaningful performance task the student applies to demonstrate knowledge, skill, strengths and needs in a realistic, authentic manner (Cooper, 2007).
Chalk-and-talk teaching method	A traditional teaching method that includes formal, expository and teacher-centered methods, during which students have to read text or listen to a lecture (Chapman & King, 2012).
Curriculum 2005 (C2005)	The curriculum developed within the framework of outcomes-based education in South Africa (South Africa, Department of Basic Education, 2012).
Dialogical	An instructional strategy used in the science classroom during which

argumentation	statements or viewpoints made are scrutinized through an argumentation protocol (Ogunniyi, 2007; Langenhoven, 2009).
Differentiation	A philosophy that enables teachers to plan strategically in order to fulfill the needs of the diverse students in classrooms today to achieve targeted standards (Gregory & Chapman, 2012).
Evaluation	A summative analysis of the student's abilities and skills at a particular time (end of a unit, semester or year) to make a judgement (Chapman & King, 2012).
Feedback	The educator's written or verbal comments related to the student's work or responses (Black & Wiliam, 2009).
Formal assessment	Tools that collect specific, observable information and contribute to a grade, under controlled conditions, like class tests and examinations (Gipps, 1994).
Formative assessment	Ongoing daily assessment before, during and after instruction to identify needs and provide continuous feedback (Gipps, 1994).
Informal assessment	A process using quick, efficient tools to gather reactions or responses in a casual, yet informative way (Gipps, 1994).
Lecture	A carefully prepared oral presentation of a subject by a qualified expert. It is usually rather formal (Chapman & King, 2012).
National Curriculum Statement (NCS)	The curriculum that emerged from the review of C2005 (South Africa, Department of Basic Education, 2012).
Outcomes-Based Education (OBE)	Education policies and curriculum based on outcomes (South Africa, Department of Basic Education, 2012).
Revised National Curriculum	The revision of the NCS (South Africa, Department of Basic Education, 2012)

Statement (RNCS)	
Scaffolding	The process wherein an educator (or more knowledgeable other) models or demonstrates how to solve a problem, steps back and provides assistance when needed (Vygotsky, 1978).
Self-assessment	A meta-cognitive process to determine personal strengths and needs (Gipps, 1994).
Socio-cultural construction	The construction of knowledge with reference to contextual practices and the building or constructing that occurs in students' minds when they learn. During this process, students construct their knowledge actively, rather than mechanically 'ingesting' information from their teacher or textbooks (Ogunniyi, 2005).
Student achievement	This is the result of the assessment of the student at the end of a section of work (Cooper, 2007).
Student performance	This refers to the complete record of assessment of a student during the learning process (Cooper, 2007).
Summative assessment	The evaluation of student work occurring at the end of a unit or period of study (Black & Wiliam, 2010).
Traditional Knowledge	A system of thought that is anthropomorphic, monistic, and metaphysical in nature (Jegede,1997, Ogunniyi, 1988)
Western Science conception	A system of thought that is mechanistic in nature, seeks empirical laws, principles, generalizations, and theories (Jegede, 1997; Ogunniyi, 1988).
Worldview	Thought system that is a culturally dependent, generally subconscious, fundamental organization of the mind, which manifests itself as a set of presuppositions that predisposes one to feel, think,

	act, and react in a certain predictable manner (Cobern, 1993).
Zone of proximal development (ZPD)	The difference between what a student can do without assistance (development level) and what the student can do with assistance (actual level) (Vygotsky, 1978).

ABBREVIATIONS AND ACRONYMS

AfL	Assessment for Learning
C2005	Curriculum 2005
CAPS	Curriculum Assessment Policy Statements
CAT	Contiguity Argumentation Theory
DAAFLIM	Dialogical Argumentation Assessment For Learning Model
DAIM	Dialogical Argumentation Instruction Method
DBE	Department of Basic Education
FET	Further Education and Training
N2-course	Second level of a course during a TVET national qualification
NOIKS	Nature of Indigenous Knowledge Systems
NOS	Nature of Science
NOSIKS-Q	Nature of Science and Indigenous Knowledge Systems Questionnaire
OBE	Outcomes-Based Education
TAP	Toulmin’s Argumentation Pattern
TVET	Technical and Vocational Education and Training
ZPD	Zone of Proximal Development

CHAPTER 1

INTRODUCTION

1.1 Introduction

The political changes in South Africa since 1994 led to transformation in the education sector in terms of access, equity and quality at pre-school, primary, secondary, post-school and tertiary levels. Several authors (Christie, 1990; Jansen, 1990; 1993; Kallaway, 1989) have noted the need for curriculum change and teaching methodology to make education more relevant to the new South African context and the objectives of the democratic dispensation. The increasing number of students migrating from historically disadvantaged education institutions to more advantaged education institutions reduced the homogeneity of the student populations and cultures. Mouton et al. (2012) assert that most ex-model C (historically advantaged) schools had little difficulty to implement Outcome-based Education (OBE) compared to other schools in the country, because the new curriculum was merely formalizing long-standing practices that was the norm. Therefore, many Black township children was clamoring to get into ex-model C schools, which indeed happened.

These changes at the education institutions necessitate research studies that will help to address the challenges arising in teaching and learning in multi-cultural classrooms (Fataar, 1997). Furthermore, the dropout rate in high schools, grade 9 – 6,5% and grades 10 and 11 – about 11,6%, leads to an increased enrolment at post-school FET (Further Education and Training) institutions and TVET (Technical and Vocational Education and Training) colleges (Weybright, 2017). Students at these colleges face specific challenges in terms of learning and assessment.

There is considerable interest in curricular and pedagogical reform that will support students from diverse backgrounds and prepare them for the challenges of the national economy and responsible citizenship. To address these objectives, TVET colleges employ a career-oriented approach through work-integrated learning (WIL). Addressing the country's skills deficit requires in-depth research to assess the myriad factors that influence learning, performance and assessment, especially in the context of an ever-changing education system.

Assessment, which a vital component of instruction, is crucial in any educational process (Chapman & King, 2012). Assessment determines the success or failure of an educational system. Education authorities and curriculum developers use the results of assessment processes for curriculum planning and development. Flaws in the assessment processes can be detrimental to the educational process and institutional planning. Weaknesses in assessment processes may be the result of several factors, such as teaching and learning strategies, language of instruction, teacher competency and the economic and socio-cultural differences of students (Christie, 1990). In many instances, assessment does not form part of formal instruction, but has become a tool solely for summarizing what students have learned and for ranking students and institutions (Black & Wiliam, 2009). The consequence of this is that over time the reciprocal relationship between teaching and assessment seems to have been lost from sight. Unsurprisingly, lecturers may see assessment as being external to their everyday practice, because it is overwhelmingly associated with the competitive evaluation of institutions, lecturers and students.

The assumption underpinning this study is that instruction and assessment processes should be integrated, contextual and relevant to the lived experiences of students. It is essential to consider the socio-cultural background and the dominant worldviews students hold with regard to their conception of knowledge, especially scientific knowledge. The perception of formal knowledge and everyday knowledge play a very important role in the teaching, learning and assessment of students. Among others, these include the characteristics of the students, their socio-cultural backgrounds, motivation for learning, learning styles and their views about what teaching, learning and assessment involve (Gregory & Chapman, 2007). Other considerations also include characteristics of the lecturer, their socio-cultural background, teacher training and professional development opportunities and their competency in the subject content and personal views about teaching and learning.

1.2 Background to the study

The education system in South Africa consist of three bands, namely General Education and Training (GET) – Grades R to 9; Further Education and Training (FET) – Grades 10 to 12; and

Higher Education and Training (HET) – colleges and universities. The GET band is further divided into three phases, namely the Foundation Phase – Grades R to 3, the Intermediate Phase – Grades 4 to 6; and the Senior Phase – Grades 7 to 9 (South Africa, Department of Basic Education, 2012). The primary school sector accommodates Grades R to seven; the high school sector Grades 8 to 12; and the higher education sector comprises post-school learning at colleges and universities.

The post-school education sector spans across the FET and the HET bands and includes FET colleges and TVET colleges that cover the high school curriculum as well as technical and career-specific courses. The qualifications offered by these post-school institutions range from short-course certificates to national diplomas. The major objective of the post-school sector, in particular the TVET colleges, is to offer vocational, occupational and artisan education and training to students older than 16 years who exited school prior to or after Grade 12. Responsible older adolescents and adults who are serious about following an education and training program with a view to acquiring marketable skills are assumed to be the target student group. The 50 public TVET colleges nationally offer a very diverse range of about 300 courses; and the length of these courses and the admission criteria depend on the nature of the particular course. The Department of Higher Education and Training (DHET) coordinates examination, assessment and certification of core programs. Furthermore, the TVET colleges offer two programs, NCV (National Certificate Vocational) and Report 191 (NATED) programs, which are quality assured by an independent body known as Umalusi (council for quality assurance in General and Further Education and Training).

The Department of Basic Education (DBE) administers the South African basic education system, i.e. school education from Grade R to Grade 12, and the Department of Higher Education and Training (DHET) administers post-school education and tertiary education. The DHET implements the Report 191 internal continuous assessment (ICASS) guidelines to prepare students for external national examinations through formal assessment activities that support teaching and learning and build up marks that count towards final examination results. Assessment using the ICASS guidelines, based on the subject syllabi and the National Policy on the Conduct, Administration and Management of the Examination of Formal Technical College Instructional Programs (FTCIP) determine students' performance. Internal summative assessment for Engineering Studies consists of two tests (Fourth Week test and Eight Week test) and students must obtain a minimum term mark of 40% to gain access to the national examination (South Africa, Department of Education, 2001a). Table 1.1 depicts the weightings of the different forms of summative assessment for the Report 191 programs.

Table 1.1: Weightings of components of assessment tasks constituting the final mark across Report 191 programs

Career path (Report 191)	Test 1 (4th Week test)	Test 2 (8th Week test)	Term mark	Trimester examinations
Engineering Studies (N1–N6)	30% of term mark	70% of term mark	40% of final mark	60% of final mark

However, the FTCIP document states that colleges may require one or two additional, supporting formative assessment tasks internally, which will not form part of the internal continuous assessment (ICASS) mark but gauging the students' learning progress. Such formative assessment tasks may include short tests, assignments, quizzes, observations, practical demonstrations, discussions or informal classroom interactions. These assessment activities administered to support the teaching and learning process, to provide feedback to the students and to inform planning for teaching. According to the ICASS guidelines, supporting formative assessment tasks are not "separate from learning activities taking place in the classroom, but should serve as building blocks to summative assessment" (South Africa, Department of Higher Education and Training, 2019, p. 6).

1.3 Rationale and statement of the research problem

The constant changes in the outcome-based education (OBE) curriculum advocates for a formative assessment classroom supporting students in becoming self-regulated learners. When putting formative assessment into practice, the teacher gathers evidence of the students' learning, and based on the identified learning needs, adapts instruction or feedback to meet these needs (Granberg, 2021). This observation and the author's master's dissertation (George, 2014) on the Dialogical Argumentation Instruction Methodology (DAIM) and the instruction of science inform the rationale of this study to address the lack of focus on explicit formative assessment. A particular issue of concern is the assessment of the conception of students in each learning space of the DAIM as well as how the teaching of the subject content relates to the student's worldview to enhance conception. Proponents of formative assessment assert that students develop a deeper understanding of their learning when the essential components of formative feedback and cultural responsiveness features centrally in the instruction process (Clark, 2011). Even with growing international agreement among the research community about the benefits of formative assessment in improving student learning, examination performance and promoting life-long learning; the latest educational reforms in South Africa seem to lead to administratively uncongenial examination-driven classroom practices (Mouton & Strydom, 2012).

The author also observed a lack of emphasis on formative assessment in the teaching of Engineering Science at TVET Colleges. Furthermore, there exists an operating assumption that all students in a TVET College classroom have the same socio-economic and educational backgrounds and learn in the same way (Gregory & Chapman, 2012). Teaching methodologies should consider the backgrounds of different students and individual learning styles. Formative assessment processes could become important functions of the promotion of students' learning. This promotion of learning could contribute to the mastery of course content by students. Formative assessment activities could also serve to assist students to develop new knowledge and skills and consequently contribute to increasing summative assessment performance (Black & Wiliam, 2009).

1.4 Aim of the Study

The central concern of this study focuses on enhancing of the conception of TVET College science students using an alternative teaching methodology (DAAFLIM) in the science classroom. More specifically, the study aimed at:

- Creating TVET science students' awareness about natural phenomena and the nature of science tenets.
- Exploring the effects of DAAFLIM on the students' conception about natural phenomena and the nature of science tenets.
- Determine whether the students' conceptions of the selected concepts relate to their age, gender and cultural background.

1.5 Research questions

In pursuing the aim of the thesis, this study seeks answers to the following questions:

1. What conceptions of selected topics such as; natural phenomena and nature of science (NOS) did E-group and C-group students hold before and after being exposed to DAAFLIM and TIM respectively?

2. Are the E-group's conceptions of the selected topics related to their age, gender or cultural backgrounds?

3. Are the conceptions of the selected science topics: SI-units, Dynamics, Statics and Energy held by the E-group significantly different from those held by the C-group using CAT, TAP and ZPD as units of analysis?

1.6 Theoretical framework

A theoretical framework positions the research in the discipline or subject in which the researcher is working. It explains the theories that underpin the research, helps to make explicit assumptions about the interconnectedness of the concepts used, and indicates how they relate to the world (Creswell, 2009). Henning, Van Rensburg and Smith assert that the theoretical framework also provides an orientation to the study and reflects the stance of the researcher in the research field. They assert that:

> The theoretical framework is the lenses through which you view the world. An educationalist would view the world in a different way to, say, a sociologist or a psychologist, depending on their research topics and the purpose of their inquiries. (p. 55)

This study is underpinned by Toulmin's Argumentation Pattern (Toulmin, 1958), the Contiguity Argumentation Theory of Ogunniyi (2007a) and the constructivist theories of Vygotsky (1978). These theoretical constructs help to shape and guide this research in terms of the construction of knowledge. They complement each other and share the fundamental notion of many other constructivists that "… constructivism involves the transfer of knowledge from the knower to the student, but actively constructed by the student, drawing from prior experience" (Ausubel, 1968; Driver et al., 1994).

1.6.1 Toulmin's Argumentation Pattern.

Researchers use Toulmin's Argumentation Pattern (TAP) in science education to promote scientific discourses in the classroom because it is more conducive to the inductive-deductive logical forms of reasoning predominant in most science discourses. The TAP model analyses the argumentation discourse to determine the quality of an argument. Erduran, Simon and Osborne (2004) explain TAP as an interconnected set consisting of a claim, data supporting the claim and warrants that provide a link between the data and the claim, as depicted in Figure 1.1. This model also includes backings that strengthen the warrants and rebuttals, which point to the circumstances under which the claim would not hold true. Toulmin (1958) believed these elements were essential to constructing a meaningful argumentation process.

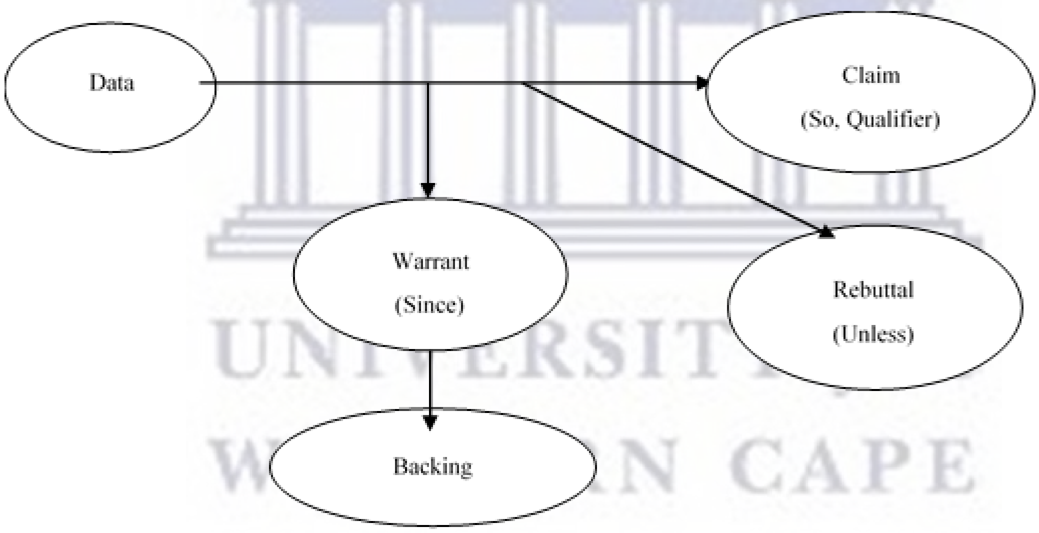

Figure 1.1: Elements of Toulmin's Argumentation Pattern (Toulmin, 1958/2003)

Many disciplines, including law, philosophy and computer science use the fundamentals of TAP (Erduran et al., 2004). This study adopts and uses TAP in Engineering Science to enhance students' understanding of selected science concepts during formative assessment activities. Useful as TAP is as unit of analysis it does not refer to the cognitive process involved in knowledge building, changes in perception or why in fact arguers change their minds in a discourse. It probably construes the whole process purely as a logical process. However, CAT construes knowledge building or changes in perception as a cognitive process.

1.6.2 Contiguity Argumentation Theory. The Contiguity Argumentation Theory (CAT) as espoused by Ogunniyi (2007a&b) construes learning as a dynamic cognitive process influencing an individual's mental state or worldview from one context to another. CAT goes beyond the logical process of reasoning as well as fills and describes the cognitive and metaphysical gap that TAP is not able to cover, because it explains the personal, non-logical experiences and beliefs of an individual. This theory contends that a worldview that is dominant in a given context may become the suppressed in another context or may be the assimilated into a more dominant worldview:

> CAT holds that claims and counter claims on any subject matter within fields [for example, religion and science] can only be justified if neither thought system is dominant. There must also be valid grounds for juxtaposing the two distinctive worldviews within a given dialogical space. The role of such a dialogical space is to facilitate the process of re-articulation, appropriation and/ or negotiation of meanings of the different worldviews. Students must therefore be able to negotiate the meanings across the two distinct thought systems in order to integrate them (Ogunniyi, 2007a, p. 33).

Ogunniyi (2007a) asserts that five categories of conceptions can navigate within an individual's mind or among individuals involved in dialogical exchange in order to justify scientific and/ or metaphysical conceptions. These five categories exist in dynamic states of flux in a person's mind, namely:

- **Dominant mental state** – when it is the most generally acceptable in a given context.
- **Suppressed mental state** – when a more adaptable mental stage overpowers another dominant cognitive stage.
- **Assimilated mental state** – when the dominant mental stage is absorbed into another, more adaptable mental stage.

- **Emergent cognitive state** – when an individual has no previous knowledge of a given phenomenon.
- **Equipollent mental state** – when two competing ideas or worldviews tend to co-exist in the mind of the individual without necessarily resulting in a conflict.

1.6.3 Social Constructivism. Constructivism in education theory claims that humans are better able to understand the information that they have constructed themselves. According to constructivist theories (Von Glaserfeld, 1995; Piaget, 1980; Brunner, 1961; Vygotsky, 1962; Dewey, 1929), learning is a social advancement that involves language, real-world situations and interaction and collaboration among students. The students are central in the learning process. Our prejudices, experiences, and both physical and mental maturity affect learning. When motivated, the student exercises his will, determination and action to gather information selectively, convert it, formulate hypotheses, test these suppositions via applications, interactions or experiences, and draw verifiable conclusions. Constructivism transforms today's classroom into a knowledge construction site.

Lev Vygotsky, known for his theory of social constructivism (1978), opined that learning and development is a collaborative activity; and that cognitive development takes place in the context of socialization and education. Vital cognitive tools provided by culture, such as history, social context, traditions, language and religion help to transform the perceptual, attention and memory capacities of individuals. For learning to occur, the individual first makes contact with the social environment on an interpersonal level and then internalizes this experience. The earlier notions and new experiences influence the individual who then constructs new ideas. Vygotsky (1978, p. 56) cites the example of a child pointing a finger. The behaviour, which begins as a simple motion, becomes a meaningful movement when others react to the gesture. In a Vygotskian classroom, there will be discovery through teacher-student and student-student interaction. Some of the cognitive strategies that group members will bring into the constructivist classroom are questioning, predicting, summarizing and clarifying, resulting in dialogical argumentation. The constructivist approach form part of both the traditional instruction method (TIM) and the dialogical argumentation and assessment for learning instruction method (DAAFLIM), received by the C-group and the E-group respectively.

1.7 Conceptual framework

A conceptual framework represents the researcher's synthesis of literature to explain a phenomenon. It maps out the actions required in the course of the study given the researcher's previous knowledge of other researchers' points of view and his observations on the subject of research. In other words, the conceptual framework depicts the researcher's understanding of how the particular theories and concepts in his study connect with each other. It identifies the theories and concepts required in the research investigation. It is the researcher's 'map' in pursuing the investigation (McGahie, 1986).

This study integrates an argumentation framework underpinned by Toulmin's Argumentation Pattern (TAP) (1958/2003) and Ogunniyi's (2007a&b) Contiguity Argumentation Theory (CAT). Fundamentally, these theoretical constructs are, to some extent, in agreement with socio-cultural constructivism as espoused by Vygotsky (1978). Vygotsky's theory of socio-cultural constructivism refers to the concept of zone of proximal development (ZPD), emphasizing the importance of the social interaction in learning and cognitive development. Furthermore, it highlights the crucial role of the responsive educator who assists thinking and action between the student and the environment, developing the students' cognitive capacity. Vygotsky asserts that language is very important in developing higher cognitive functioning and allows a learner to interact with other people by trading ideas, which is very important in the dialogical argumentation process. These theoretical constructs form the foundation of the Dialogical Argumentation Instruction Model (DAIM), creating discussion spaces within the classroom that align to the learning objective. This is an interactive process directed at providing all participants with opportunities to express their views in a non-threatening environment; the shared commitment is towards respectful presentation of opinions (Osborne, Erduran & Simon, 2004). The DAIM allows spaces for this dialectic exchanging of ideas and opinions. However, the DAIM lacks the explicit and intentional reference to formative assessment, crucial in any instructional process; and the role of a responsive educator gauging, creating and capitalizing upon moments of synchronous contingencies. This study has therefore, incorporated research done by Sadler (1989), Gipps (1994), Black and Wiliam (2009, 2010), Stiggins (2002) and Rosenshine (2012) on formative assessment into the DAIM framework. A combination of the different theoretical constructs has eventuated into the so-called Dialogical

Argumentation and Assessment for Learning Instructional Model (DAAFLIM) used for this study as illustrated in Figure 1.2. The educator initiated student-centred instruction, focusing on the students' progress at specific learning instances.

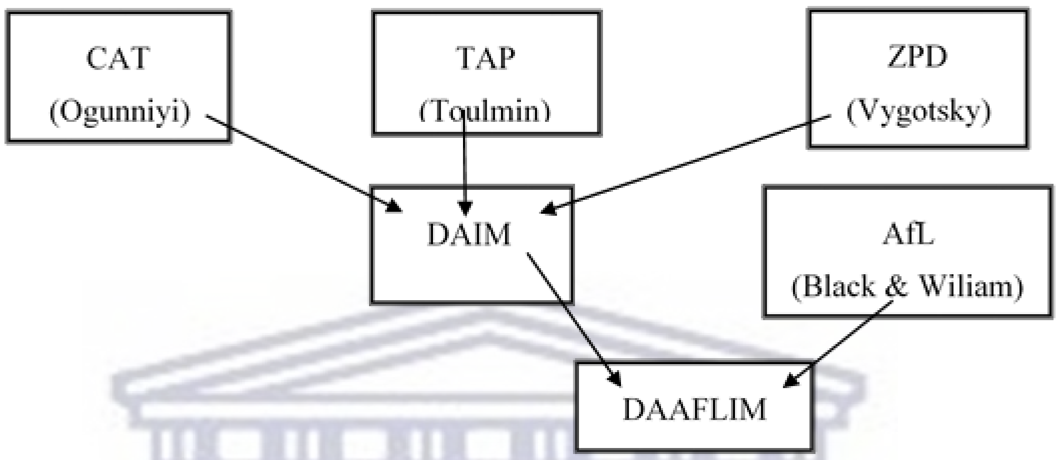

Figure 1.2: Conceptual model of the DAAFLIM

Gipps (1994) describes the intricate relationship between instruction, learning and assessment in the classroom. This relationship represented in the top, 'unboxed' part of Figure 1.3 is suggesting an interactive relationship between assessment, learning and teaching, and relating them to the perceptions students and teachers hold. The 'boxed' part of Figure 1.3 shows two main uses of assessment, namely formative assessment and summative assessment, in relation to students' learning and the assessment models used for the context of this study. Summative assessment takes place when the evaluation of student work occurring at the end of a unit or period of study; and formative assessment is a process used by educators and students during instruction that provides feedback to adjust ongoing teaching and learning to improve students' achievement of intended instructional outcomes (Stiggins, 2002). The focus of formative assessment in this study is Assessment for Learning (AfL) that contributes to Assessment of Learning (AoL); therefore, it forms a very important building block of summative assessment.

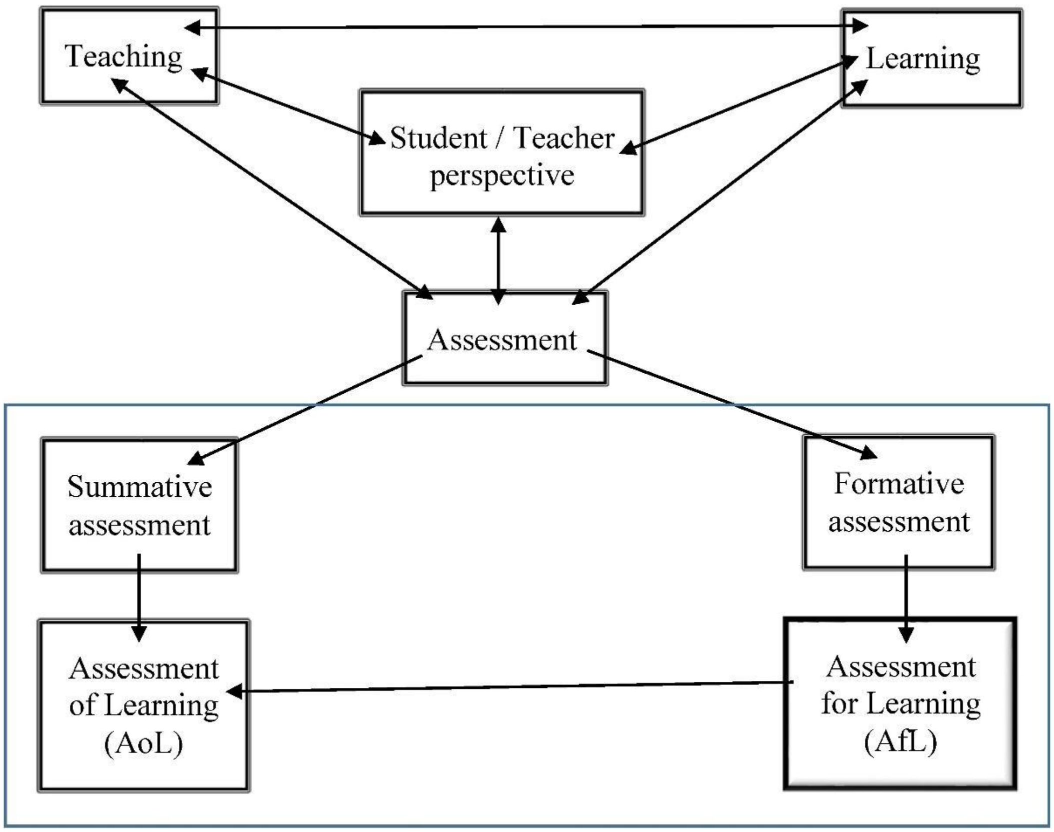

Figure 1.3: Relationships between different components of assessment (Kelly, 2007)

1.8 Delimitations

Theofanidis and Fountouki (2019) assert that; "delimitations are concerned with the definitions that the researchers decide to set as the boundaries or limits of their work so that the study's aims and objectives do not become impossible to achieve". This study focused on science in general, but only concentrated on selected engineering science topics: SI-units, Dynamics, Statics and Energy, because of time available to conduct the study at the campus. The focus of the study was not the summative assessment of the subject content, but the formative assessment processes during the instructional activities. The main factors forming the boundaries of this research project were:

- The study design considered that the DAAFLIM might have been a new experience for the participants and, therefore, encounters with the DAAFLIM might have been limited. The researcher used two weeks to induct the E-group into the protocol and practice in the

DAAFLIM framework as a means of promoting familiarity with this new instructional approach (the researcher exposed the C-group to DAAFLIM after the study).

- The period of the study - first eight weeks of the second trimester - only allowed four topics to be covered.
- The early stage of the trimester contributed to the maximum inclusion of participants, because the students were fresh, not fatigue of exposure to too much work.
- The concurrent intervention period of the E-group and C-group students at the different campuses eliminated possible contamination of data.

1.9 Significance of the study

This research has important educational and social value in South Africa and occurs at a time when solutions sought to improve instructional methods, to affect students' performance positively and, in particular, the national skills development. This study explores an important concern in contemporary local and international education debates that has not been satisfactorily resolved and remains contested, namely the importance of localized learning and formative assessment in the South African education curriculum.

It is of practical significance as it draws together insights from different perspectives and sources of data, which policy makers and curriculum designers need to consider. It also opens up the possibility of further debate between academics, curriculum theorists, educators and the public. The National Department of Basic Education requires the development of a context-based curriculum, which will make course content relevant to indigenous knowledge (South Africa, Department of Basic Education, 2012). Research on context-based teaching and learning, and theoretical research on formative assessment in the TVET college sector is still lacking in South Africa. There is a need for further exploration of context-based science teaching and learning, understanding of basic scientific concepts, higher order learning abilities and problem-solving skills of students. This study provides alternative formative assessment strategies to enhance students' conceptions and consequently their summative assessment performance.

Chapman and King (2012) assert that developing nations, like South Africa, are experimenting extensively with curricula to make teaching and learning more effective. Students at many learning institutions are experiencing learning challenges traceable to teaching methodologies and assessment strategies (Black & Wiliam, 2009).

In 18 years as a high school educator and TVET college lecturer, the author of this study has observed negative effects on the quality of teaching and learning caused by educators focusing on completing the subject content and rote learning of facts by students for tests and examinations. Students consistently complain about the poor quality of teaching methodologies and assessment procedures, including ineffective and unenthusiastic presentations by educators, too much lecturing, and not enough interactive dialogue with students, failure to encourage active independent learning, poorly specified course objectives, and not regarded as partners in the learning process. The finding of this study may help lecturers to modify their methods of instruction and may contribute to an improved quality of learning.

1.10 Thesis layout

Chapter 1: Introduction. Chapter 1 describes the motivation for the study, provides the aims of the study and outlines the methodology and research frameworks that guided it. The chapter gives the rationale for the study and describes the role and importance of assessment in education and the need for models of assessment alternative to traditional standard assessment models that would provide more information about students' competencies. In addition, it gives an overview of the structure of the study.

Chapter 2: Review of related literature. Chapter 2 discusses the literature relevant to this study. It explores literature on the functions of assessment and its role in the science classroom. Problems of the traditional assessment model justify the call for alternative models of assessment in a re-conceptualization of assessment strategies of students' learning. It also interrogate, compare and explore the CAT, TAP, constructivism and formative assessment theories underpinning the DAAFLIM.

Chapter 3: Research design and methodology. This chapter focuses in detail on the research design and methodology for this study, which embraces the quantitative and qualitative approaches. It describes the sampling procedures used to select the participants, the different instruments, especially the DAAFLIM, that were developed and used as an intervention pedagogical model, the administration of the data collection process and the data analysis. The methodological challenges experienced in the course of the study are briefly noted.

Chapter 4: Results and discussion. Chapter 4 documents the results obtained with the data collection instruments, classroom observation, the SAT and interviews in order to determine the worldviews (NOS and NOIKS) held by the students and the effectiveness of the DAAFLIM intervention. The results are qualitatively and quantitatively analysed and discussed in detail.

Chapter 5: Conclusions and recommendations. This final chapter summarizes the main findings and answers the research questions. It also briefly discusses the findings and conclusions drawn from the results. The implications of the results in various sectors and recommendations based on the findings highlight suggestions for further research.

Related appended material. The appendices comprise of the syllabus objectives and the relevant content from the topics used in this study, letters of request to Northlink TVET College and the University of the Western Cape, a letter granting permission to conduct the study and the data collection instruments.

1.11 Chapter summary

This chapter introduces the thesis giving a background and rationale for the research study. The aims of this study are also spelt out with the three research questions that will be explored. The Toulmin's Argumentation Pattern, Contiguity Argumentation Theory and social constructivism forming the theoretical framework of this project was explained and it was also indicated how these theories come together to form the conceptual framework used. The delimitations of this study indicating the scope of the study was out-lined. This chapter ends highlighting the significance of the study and gives a layout of the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a reflective overview of studies, research reports, reviews of literature and commentary notes on research work that relate to the concepts underpinning this study. The review is organized into various concepts relating to teaching, assessment and conception, namely constructivism, dialogical argumentation, assessment and worldviews. The focus of this chapter is to indicate how these concepts are central to the teaching and learning of science concepts.

2.2 Curriculum reform in South Africa

2.2.1 Education reform in schools. Before 1994, the South African education system discriminated based on 'race', to the advantage of the White population, using apartheid legislation in education policies. In this study, the notional identity 'Black' describes people who are not White. This meaning of 'Black' includes people of indigenous heritage (known at various times as Native, Bantu, Black and African); people of indigenous and European heritage (including people known at various times as Griquas, Bastards, Cape Coloureds, Cape Malays and Coloureds) and people of Indian descent (defined in apartheid legislation as 'Asian'). In the discussion in Chapter 3 and elsewhere, a further distinction within the 'Black' grouping is made between 'Africans' and 'Coloureds', when there is a pertinent material difference in the respective conditions of the two Black populations, for example, the so called Coloureds enjoyed more privileges than Blacks during the apartheid regime. Lastly, it should be noted that for the purposes of this study, the relevant issues pertaining to Coloureds apply in general to the population of Indian descent as well and therefore no specific definition of 'Indian' has been made within the data or the discussion (Christie, 1990).

After 1994, when the democratically elected African National Congress (ANC) government came into power, education was one of the first areas targeted for reform and redress. Curriculum revision began immediately after the election. In 1997, the new National

Department of Education launched the new curriculum, Curriculum 2005 (C2005). C2005 based on the principles of outcomes-based education (OBE) “involves the most radical form of an integrated curriculum” (South Africa, Department of Education, 2002). Several problems soon emerged with implementation of the C2005.

Firstly, the South African education sector spans a range of contexts from affluent urban First World conditions, to impoverished rural Third World. Thus while some schools could boast with magnificent buildings and facilities that would rank among the best in the world, others operated in broken-down buildings, lacked doors and windows, electricity and sanitation, and many had few books and other learning resources (Rogan & Grayson, 2003). Having accumulated much better resources in an environment boasting picture-rich, including better qualified teachers with smaller classes, former White schools also known as Model-C schools had few problems implementing the curriculum change and felt that they had been teaching close to the intended instructional methodology for years. Most former Black schools properly implemented the changed curriculum, because of a lack of resources and capacity (Chisholm & Leyendecker, 2008). Secondly, a detailed plan implementing these new ideas in under-resourced classrooms is absent in the curriculum reform according to Jansen (1998). Jansen (1998) argues further that curriculum reform and OBE was primarily an attempt to push something innovative onto the schools at all costs in order to reclaim political credibility, and as such has very little to do with bringing about substantive change to teaching and learning in the classroom. Thirdly, according to Jansen and Christie (1999), the main reasons for the criticism of the new curriculum were the critical lack of a solid learning material base to support the pedagogy and philosophy of this progressive curriculum and the lack of confident and competent teachers to manage the curriculum. I shared the sentiments with Jansen and Christie, being part of the teaching corpse at that period, teachers were not actively involved in the curriculum planning and in-service training was rushed.

A review committee that comprised of distinguished academics, officials and teachers revised the C2005; leading to the launch of the National Curriculum Statement (NCS) for grades R – 9 and the Revised National Curriculum Statement (RNCS) for grades 10 - 12. The NCS and RNCS became policy at the end of 2001. The NCS and the RNCS were not a new curriculum, but a modified C2005 with fewer curriculum design features, fewer outcomes, clear guidelines to teachers on what to teach, and implementation guidelines (Howie, 2002).

However, educators experienced challenges and problems in implementing the NCS and RNCS, and a panel of experts reviewed the two policy documents and developed a set of recommendations. The panel of experts recommended that the two National Curriculum Statements rationalized into a single coherent document. Furthermore, the panel recommended that this new document should be “clear, unambiguous, measurable and based on essential learning as represented by subject disciplines” (South Africa, Department of Education, 2009, p. 49). A single comprehensive document developed for each subject to replace Subject Statements, Learning Program Guidelines and Subject Assessment Guidelines in the NCS and RNCS, called the Curriculum Assessment Policy Statement (CAPS) came into effect in 2012.

Although the transformation and changes in the national curriculum directly affected the mainstream schooling system, it also influenced the changes in the curriculum and subject guidance of the course of TVET colleges. The fact that TVET colleges fall into the FET band of the education system links it to the national curriculum, however, the content is occupation orientated to address specific skills and abilities in the labour market. The next section explains how the technical colleges evolved into TVET colleges in terms of structure and curriculum.

2.2.2 Transformation from technical colleges to TVET colleges. In 1994, ‘the vocational and technical component of the South African education system consisted of 152 technical colleges located in numerous education departments, each department with its own system of government, management and funding mechanisms’ (South Africa, Department of Higher Education and Training, 2013). The period from 2002 to 2006 saw the consolidation of the merger process, where 152 technical colleges were merged to form 50 public further education and training (FET) college administrations dispersed across approximately 254 college campuses (the public FET colleges were renamed technical and vocational education and training [TVET] colleges in 2014). The completion of this process brought about the development and training of college councils, the appointment of principals at each of the 50 colleges and the development of common administration and management systems across the various sites of the colleges (South Africa, Department of Higher Education and Training, 2013).

The main objective of the various TVET colleges is to provide education and training for students who left the mainstream schooling system without completing it. This TVET system equips students with the skills, knowledge and aptitudes required by the labour market for various occupations. The colleges mainly provide education and training for mid-level skills in the engineering and other technical fields in order to develop the economy of South Africa (South Africa, Department of Higher Education and Training, 2013). The National Certificate Vocational [NC(V)] level 1 to 4 programs, approved in 2006 led the way to NC(V) programs providing skills to TVET college graduates preparing them for industrial careers (South Africa, Department of Education, 2006). NC(V) initially intended to replace the vocational and technical system known as NATED programs or Report 191 belonging to the old National Education Department. NATED was purposely set up in 1935 to meet the training requirements of the labour forces of the South African harbours and railways systems (South Africa, Department of Education, 2008). The NATED courses consist mainly of theory-based curricula, organized into a two-year cycle of trimesters or semesters, covered in the N1–N6 programs. This is in contrast to the origin of the NATED courses where its mandate was largely practical (South Africa, Department of Education, 2008, p. 4).

The main objective of the transformation processes and curriculum changes in the TVET colleges and mainstream schools are to produce competent and skilled citizens. At tertiary education institutions aspects such as teaching and learning, research and innovation, and community engagement and partnership are viewed essential in curriculum transformation and linked to capacity development and identity of the institution. However, there is no available framework in the education transformation literature to show how these three aspects can be equally focused on in TVET colleges in South Africa (Mendy & Madiope, 2020). Therefore, I am of the opinion that these aspects should be central in the curriculum transformation processes at TVET colleges. Lecturers and students are at the coalface, experiencing the challenges in the classroom and in the best position to guide students. Black and Wiliam (2010) uses a system engineering analogy, comparing the classroom with a black box. They assert that education authorities produce external inputs - curriculum, resources, examinations, etc. - for the black box and expect positive outputs - high pass rates, competency, good performance, etc. However, the reform initiatives (inputs) do not support educators and students, who are the active role players inside the black box. Therefore, educators should be actively involved in the curriculum development.

The problems experienced and expressed by educators during the curriculum reform process were justified. It would be irrational and naïve to expect educators to accept educational reforms without any objections. Little (2001) asserts that:

> The new curriculum reform proposals presented to teachers, subjected to interpretations, resulted in the formulation of new meaning(s), which may or may not support the new curriculum. This will might have negative consequences for the implementation of the new curriculum in the classroom. (p. 26)

Many researchers enquiring into educators and policy (Guskey, 1995; Crossley & Vulliamy, 1996; De Clercq, 1997; Jansen, 1997; Jansen & Christie, 1999; Spillane & Callahan, 2000) have pointed out the centrality of the role of teachers as key to the success of curriculum reform. I am of the opinion that the educator's voice offers substance and deeper understandings of the complexities at the levels of policy implementation in the classroom. Just informing educators to implement a new curriculum and to change their teaching methodologies will obvious lead to very little support and cooperation from educators. Nakabugo and Siebörger (2001) support this concern and found that educators will not change their style of teaching if simply informed of the need for a change in style of teaching, nor will they abandon one instructional strategy for another or consistently use new 'improved' strategies prescribed to them. Such teachers are likely to revert to the traditional instruction methodology.

OBE in TVET colleges and mainstream schooling system advocates the use of teaching methods that encourage a more learner-centered classroom (South Africa, Department of Education, 1997). Contemporary understandings of learner-centered education are consistent with Vygotskian cognitive psychology. OBE acknowledges the way the mind works and its main aspects are in line with the constructivist learning theory: knowledge is not transmitted but constructed in the mind of learners; learning is a process in meaning and is developed on the basis of prior knowledge; and language influences culture and thinking. Therefore, we need to focus on what happens inside the 'black box' – the activities and interactions in the classroom, and how knowledge construction takes place in the minds of the students. In order to understand what is happening inside the black box we have to be aware of the students' socio-cultural background, how they construct knowledge, how they interact with others and the ways they respond to synchronous intervention. The following sections deals with these factors.

2.3 Nature of Science and Nature of Indigenous Knowledge Science

Western science worldview dominated the design of science curricula during the apartheid era, emphasizing a positivist paradigm, reductionist, decontextualized and free of values pedagogies. On the other hand, the apartheid education ignored the Indigenous Knowledge worldview, which is inclusive of traditional values, holistic, communal and spiritual. Both the western science worldview and indigenous knowledge worldview are obtained through observations, impacts on individuals lives and are dynamic and changing (Mason, 2012). Policy makers and curriculum designers recognized the differences and similarities of western science and indigenous knowledge, including it in post-apartheid science curricula. In this way the, acknowledging the relationship and contribution of indigenous knowledge worldview to science world knowledge.

2.3.1 Indigenous knowledge science. The term indigenous knowledge (IK) has gained prominence in recent years and refers to bodies of knowledge developed by peoples with extended histories of interaction with the natural environment. The term 'indigenous knowledge' has many meanings, including traditional ecological knowledge (TEK), local knowledge, ethno-science, folk-science, indigenous science, traditional science and folklore (Williams & Muchena, 1991). The term 'knowledge' has different meanings to different people. Therefore, in combination, the words 'indigenous knowledge' presented as a single concept has been challenging to define, because it is difficult to agree on a legally and scientifically acceptable definition of indigenous knowledge (Maurial, 1999). There is no universally accepted definition of the term and many analysts are uncertain who should be talking about this term (Semali & Kincheloe, 1999). A review of the literature shows that indigenous knowledge has been defined by various researchers (including Dei, 2000; Mwadime, 1999; Odora-Hoppers, 2002; Ogunniyi, 2009a; Onwu & Mosimege, 2004; Semali, 1999; Semali & Kincheloe, 1999; Warren, 1991). However, each of these researchers defines the indigenous knowledge differently. What emerges from the definitions is that some researchers link indigenous knowledge with that which arises locally (such as Ogunniyi, 2009b; Semali & Kincheloe, 1999), the long-term occupancy of a place (Dei, 2000), or link the term with colonialism and indirectly focus on the differences between two worldviews, namely Western Science and Indigenous Knowledge Systems (Mwadime, 1999).

2.3.2 Indigenous Knowledge and Western Science. Indigenous knowledge and western science have many similarities as well as differences (Aikenhead, 1997a; George, 1999; Jegede, 1995; Snively & Corsiglia, 2001). Indigenous knowledge and western scientific knowledge are neither completely different nor entirely the same, but display both commonalities and differences. The portrayal of western science as superior, universal and as not having the 'cultural fingerprints' makes it to be much more conspicuous than other knowledge systems. Therefore, defining 'other' knowledge systems as non-science based on the western science worldview (Gough, 1998). Le Grange (2004) supports this perspective of knowledge viewing indigenous knowledge as a particular way of understanding the world, but that it is not science.

After surveying research on indigenous knowledge, Agrawal (1995a) concludes that there are differences between the two knowledge systems. Firstly, the two systems differ on substantive grounds, because of the differences in the subject matter and characteristics of indigenous knowledge and western science. Secondly, the two systems differ on methodological grounds, because the two forms of knowledge systems employ different methods to investigate reality. Thirdly, the two systems differ on contextual grounds because traditional indigenous knowledge is more deeply rooted in its environment. However, Agrawal (1995b) opines that the distinction between indigenous and western knowledge can present problems for those who believe in the importance of indigenous knowledge for development. Agrawal asserts:

> [It is] Only when we move away from the sterile dichotomy between Indigenous and Western, or traditional and scientific knowledge, that a productive dialogue can ensue which focuses on safeguarding the interests of those who are disadvantaged. (1995b, p. 4)

Western science also mostly seeks information, which is not context-bound, while indigenous knowledge is context-bound. Indigenous knowledge proceeds from observations gained through trial-and-error, as opposed to controlled experiments in western science. Furthermore, indigenous knowledge and western science differ in their social goals as well as their means of gaining knowledge. Lastly, indigenous knowledge generated through observations and experiments in uses while western science is more abstract (Antweiler, 1996).

There are other differences worth noting. Western science has a mechanistic worldview, while indigenous knowledge presents essentially an anthropomorphic worldview (Jegede, 1995; Ogunniyi, 1988). Indigenous knowledge is holistic while western science is reductionistic in nature (Aikenhead, 1997b; Ogunniyi, 2009a). Western science breaks down data into smaller elements to understand the whole and complex phenomena and compartmentalizes science into zoology, botany, physics, chemistry, etc. Indigenous knowledge treats all aspect of science from a holistic view and views ideas and practices as one (Maurial, 1999; Mwadime, 1999). Learning in IK is generally communal, while in western science learning is an individual enterprise (Jegede, 1999. p. 125; Semali & Kincheloe, 1999, p. 103). Furthermore, western science mostly uses written records and IK transmission through oral tradition. (Semali & Kincheloe, 1999). Maurial (1999, p. 63) describes the transmission through oral traditions as *agrapha*, “not written down [directly]”. Direct experimentation and observations of the natural world informs the indigenous knowledge worldview, while observations in the western science worldview mostly takes place in laboratories (Kawagley, Norris-Tull & Norris-Tull, 1998). IK is multifaceted and can pertain to knowledge systems of indigenous people and minority cultures. Although distinct differences exist between the two worldviews, I agree with Mason’s (2012) opinion that both worldviews are permissible ways of knowing.

2.4 Socio-cultural influences and science

Cobern (1996) asserts that many non-western students struggle in science education at school because science exists in a cultural context, and teaching and learning science is often a cross-cultural activity (Fakudze, 2004). Socio-cultural knowledge arises not only from students’ ethnic backgrounds, but also from their socio-economic conditions their environment and the personal circumstances of their lives (Stears, Malcolm & Kowlas, 2003). There is evidence in the literature that the students’ socio-cultural background variables such as ethnicity and home environment have a significant influence on their achievement in school science learning (Kesamang & Taiwo, 2002; Taiwo, Ray, Motswiri & Masene, 1999; Taiwo & Tyolo, 2002).

Other factors that influence the learning of science are societal expectations, customs and traditions (Akatugba & Wallace, 1999). Many studies show that the students' socio-cultural background can prevent or impede a proper learning and understanding of science (e.g., Jegede, 1995; Jegede & Okebukola, 1989, 1991). These studies also suggest that the effective teaching and learning of school science and technology linked to economic prosperity; and that success in science can enhance the quality of life. However, some ethnic minorities tend to underachieve and struggle in school science while others, for example, Chinese minorities in western countries, can excel. Furthermore, marginalized students can experience western science as a foreign culture (Jegede & Okebukola, 1991). This foreignness is because of the difference between the students' worldviews, as determined daily from infancy by the local culture and environment, and the worldview of the scientific community (Costa, 1995; Jegede, 1995).

As a result, of the desegregation of former White and Black schools, there was an increase in the cultural and linguistic diversity of students; and some schools in South Africa changed from a mono-cultural context to a multicultural societal context. Multicultural education purports to create equal educational opportunities for students from diverse racial, ethnic, social-class and cultural groups (Banks & Banks, 1995).

Many researchers have studied the effects of culture on education systems and classroom teaching and learning (e.g. Fisher & Waldrip, 1997; Hodson, 1992; Jegede, 1999; Jegede & Okebukola, 1991). The results of these studies indicated that the cultural values of both the educator and the student influence teaching and learning processes positively. In order to be responsive and produce optimum learning educators must be aware of the cultural diversity of their students (Atwater, 1994). Non-western educators who share the same non-western socio-cultural background as their students, teaching western science might be unsuccessful in multicultural classes. I believe it is crucial that the educators in multicultural classrooms with students from non-western backgrounds should be aware of the cultural background of the student. However, the situation is even more difficult for the educator with a western background who has to teach students from non-western backgrounds (Atwater, 1994; Jegede, 1994).

I believe that students bring to the classroom ideas based on prior experience; students of different cultural backgrounds frequently interpret science concepts differently from the standard scientific view; and educators need to begin instruction by determining the prior knowledge of the students (Jegede & Okebukola, 1991; Ogawa, 1995; Snively & Corsiglia, 2001). Educators need to probe for and incorporate the prior indigenous beliefs of students (Snively & Corsiglia, 2001). Cobern (1996) asserts that contemporary way of teaching science education has little or no meaning for many students because "it fails to teach scientific understanding within the actual world in which people live their lives" (p. 589).

2.5 Constructivism

The interpretation of constructivism and constructivist approaches to learning vary widely and often seem unclear. In general, constructivism provides students with opportunities to create their own versions of knowledge of the world (Lankshear & Knobel, 2004). The very large range of literature on constructivism encompasses theoretical and conceptual variations associated with the work of major researchers including Brunner's (1961) emphasis on enacting, iconic and symbolic presentation of knowledge; Piaget's (1936) accommodation and assimilation of knowledge; and Vygotsky's (1978) bridging the zone of proximal development – with distinctions between cognitive constructivism and social constructivism.

The instruction methodologies of the C-group and E-group in this study follow the guidelines of the Curriculum Assessment Policy Statements (CAPS), clearly stating that teaching methods should encourage a more student-centered classroom (South Africa, Department of Basic Education, 2012). CAPS also encourages methodologies based on the Vygotskian socio-cultural constructivism, acknowledging the way the mind functions, positing "... knowledge is not transmitted, but constructed in the mind of students. Learning is a process in which meaning is developed on the basis of prior knowledge and language influences culture and thinking" (Chisholm & Leyendecker, 2008, p.198). It is important for educators to be aware of and manage the prior knowledge of students to mediate the learning process.

Contemporary constructivists describe the acquisition of knowledge as a building process in which knowledge is actively constructed by individuals or social communities (Brooks & Brooks, 1999; Taylor, Fraser & Fisher, 1997; Terhart, 2003; Terwel, 1999; Von Glaserfeld, 1991a). Other constructivists value the students' prior knowledge during learning, as they believe that the students' prior experiences influence how they acquire new knowledge. New information passing through the filters of students' prior knowledge and experiences is important in the creation of meaning (Feltham & Downs, 2002). Furthermore, Von Glaserfeld (1995) drew inspiration from a reinterpretation of Piaget's theory and developed a theory known as radical constructivism. According to radical constructivism, "… learning is a result of mental constructs in an individual's mind that materialize from an individual's interpretation of new experiences by drawing from an individual's past experiences" (Von Glasersfeld, 1995, p.75). Radical constructivism is not a picture or description of any absolute reality, but is a possible model of knowing and the acquisition of knowledge based on an individual's own experience, a more or less reliable world. Radical constructivism refers to both a type of learning theory and a pedagogical model, using old knowledge and experiences in the process of constructing new knowledge.

Constructivist theory acknowledges that the educator is not a transmitter of knowledge, but rather a facilitator of learning. The teaching practices in the constructivist classroom require that the students must actively participate in the activities, become more involved in the learning process and take responsibility for their own learning. Therefore, the students are not absorbers of knowledge, but active participants in constructing their own meaning based on strongly held preconceptions (Aldridge, Fraser & Sabela, 2004). Driver and Oldham (1986) also acknowledge that what the students bring with them to the learning situation is important and constructing meaning as the students interact with the environment. Therefore, I am of the opinion that students should be responsible for constructing their own meanings; making sense of new ideas by reconstructing the ideas for themselves, or discussing them with more knowledgeable peers, during group work, or by receiving new explanations from the educator. Thus, the students gradually internalize what was once external, bridging the zone of proximal development (Vygotsky, 1978).

Vygotsky (1978) posited that students' thinking and problem-solving abilities fall into three categories: those that can perform tasks independently; those that need assistance to perform tasks; and those unable to perform tasks, even with assistance. The latter lays beyond the zone of proximal development (ZPD). Formative assessment activities assist students' conception namely, classroom discussions and exercises that are done outside and inside classrooms. Educators design scaffolding processes, starting from what the students can do independently based on prior knowledge. As students continue to practice, they become able to do certain tasks independently in activities previously performed with assistance. The shifts the students gain in understanding, mastering tasks, help them to find ways of attempting the problems that they were unable to solve. The ZPD is therefore the range of abilities a student can perform with the educator's assistance. Vygotsky's ZPD, explaining how to advance students' learning process, also refers to socio-cultural perspective. Wertsch (1985) reinforces this approach by asserting that:

> Any function in the student's cultural development appears twice, or on two planes. First, it appears on the social plane, and then on the psychological plane. First it appears between people as an inter-psychological category and then within the student as an intra-psychological category. (pp. 60–61)

When scientific knowledge is constructed and communicated, it happens through the culture and social institutions of science. It is unlikely that individuals will discover such knowledge through their own empirical inquiries. Therefore, the role of the science teacher is to mediate scientific knowledge for students helping them to make personal sense of the construction and validation of knowledge claims (Driver et al., 1994).

In my opinion, the constructivist classroom maximises students' conception and consists of a program of activities from which knowledge and skills can be constructed, generated and validated. In the South African context, the roughly 40 students in such a classroom should not be passive absorbers of information; and the educator should not be the active transmitter of knowledge. The educator has an important mediating role, because he/ she must take into account the 40 different levels of what the students already know. Then, maximizing social interactions between the students so that they can negotiate meaning and provide a variety of sensory experiences (Tobin, Tippins & Gallard, 1994). Furthermore, the construction of scientific knowledge taking place within a South African context needs to consider the lived experience of the students. An instructional model is required to take on such a constructivist approach in the South African classroom. A dialogical argumentation orientated model and effective formative assessment strategies could be an appropriate constructivist approach to enhance students' conceptions, which is unpacked in the following section.

2.6 Why dialogical argumentation?

In 2015, South Africa participated in the Trends in International Mathematics and Science Study (TIMSS), measuring student achievement in mathematics and science, as well as student beliefs and attitudes towards these subjects at a national and international level. In addition, the international study also investigates curricular intentions and classroom environments. The TIMSS 2015 study found that the performance of South African Grade 9s ranked second last in terms of mathematics and last in terms of science out of 39 participating countries. South African Grade 5s ranked 47th out of 48 countries for mathematics (Reddy et al., 2016). These findings raised very important questions about the quality of the South African education system, the instructional methodologies of educators and the way our students learn in the science and mathematics classrooms.

The White Paper on Education and Training (South Africa, Department of Basic Education, 2011) states that:

> All programs of education and training should encourage independent and critical thought, the capacity to question, enquiry and reasoning, weighing of evidence and to form judgements, to achieve understanding, to recognize the provisional and incomplete nature of most human knowledge… (p.25)

The new CAPS implemented in 2012 and the curriculum guidelines of the TVET colleges emphasize the student-centered methodologies that should equip students with these learning skills. Various alternative instructional methodologies employed by lecturers to comply with new methodological approaches include exposing students to workplace-integrated learning (WIL). Lecturers took students on excursions to the industrial workplaces, used apparatus in class and invited experts from the world of work. However, the instruction methodologies and assessment processes largely remained textbook-orientated and summative assessment focused (Lawrence, 2016). In my view, the intentions of the TVET college management were well intended, but what happen in the classroom was a different story – educators still using tradition instruct methodology. For example, the college management produced and enforced systemic changes - excursions, practical work, WIL, etc. - to the 'black box', expecting positive outcomes. However, it does not address the problems inside the 'black box'.

The CAPS curriculum and TVET college curriculum defines what valid knowledge is and what knowledge transmitted to students forms an integral part of the curriculum. Ogunniyi (1988) asserts that, "There seems to be an urgent need to design science curricula that foster among students the acquisition of valid knowledge, but at the same time are sensitive to their value system" (p. 33). I consider that scientific argumentation should be an integral part of science curricula to improve students' critical thinking skills, necessary to validate or refute claims during scientific enquiry. Bricker and Bell (2008) assert that argumentation is a core epistemic practice of science, assisting students in mastering scientific concepts and encouraging them to be confident in scientific discourse. Argumentation is a crucial component of scientific enquiry in science education, involving the generation and justification of knowledge claims. Furthermore, scientific argumentation based on constructivism, in particular constructive controversy theory enables students with different incompatible views to agree on the best position based on evidence and reasoning (Johnson & Johnson, 2003). The educators should be in a position to understand how students comprehend, practice and manage the processes involved in scientific argumentation during the delivery of the curriculum. The theories of constructivism, Toulmin's Argumentation Pattern (TAP) and Contiguity Argumentation Theory (CAT) provide a guide to mapping an integrated approach to a scientific curriculum.

2.6.1 Toulmin's Argumentation Pattern (TAP). In order to participate in a scientific community, students need to know how to construct strong arguments to support their claims. Stephen Toulmin (1958) developed the Toulmin's Argumentation Pattern (TAP) influenced by the deductive reasoning of Socrates (470–399 BC), idealized formal logic of Plato (437–347 BC) and enthymeme rhetoric of Aristotle (384–322 BC). Toulmin argued that absolutism (theoretical or analytic arguments) has limited practical value and contends that many of these so-called standard principles are irrelevant to real situations encountered by human beings in daily life (Toulmin, 1958). In order to develop his contention, Toulmin introduced the concept of argument fields. He developed a different type of argument, called practical arguments (also known as substantial arguments). Toulmin's practical argument intends to focus on the justificatory function of argumentation, as opposed to the inferential function of theoretical arguments.

Toulmin contends that for a good argument to succeed, it needs to provide good justification for a claim. Toulmin proposed a layout containing six interrelated components for analyzing arguments:

- **Claims** – These are assertions (declarations without support) about what exist or values that people hold. For example, '*Thandi's weight is greater on Earth than on Mars'*.

- **Data** – These statements serve as evidence to support the assertion. For example, '*Weight of a person depends on the gravitational acceleration on a planet'*.

- **Warrants** – These statements explain the relationship between the data and the claim. For example, '*Gravitational acceleration depends on the mass of a planet'*.

- **Qualifiers** – The claim holds true under these specified conditions. For example, '*Thandi's weight will only be greater on Earth, if Earth has a greater density than Mars'*.

- **Backings** – These are underlying assumptions, often not made explicit. For example, '*The Earth is a much heavier planet than Mars'*.

- **Rebuttals** – statements that contradict the data, warrant, backing or qualifier of an argument. For example, '*Thandi's weight will be less on Earth, if she loses a limb while on route to Earth from Mars'*.

- **Counter-claims** – these are simply opposing assertions.

The appropriate formulation of these elements produces TAP, based on deductive-inductive discourses. Figure 2.1 illustrates how these elements related in terms of the argumentation process.

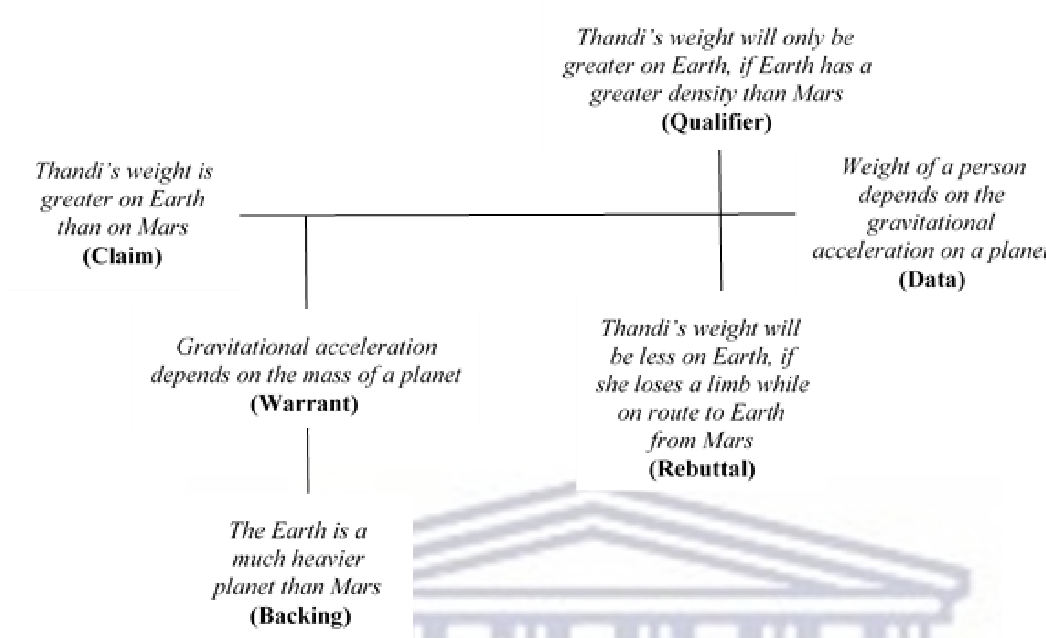

Figure 2.1: Example of Toulmin's Argumentation Pattern elements

In order to enhance students' understanding of scientific arguments, since it lends itself to a deductive-inductive classroom discourse, educators use Toulmin's Argumentation Pattern (TAP). In terms of TAP, the more the number of rebuttals used, the better the quality of the argument (Erduran et al., 2004; Osborne et al., 2004; Simon, Erduran & Osborne, 2006). Erduran et al. (2004) categorize the TAP into seven levels of argumentation in order to determine the degree of an argumentation process. The levels progress from level zero to level six as indicated in Table 2.1.

Table 2.1: Levels of argumentation

Quality	Characteristics of an argumentation discourse
Level 0	Non-oppositional
Level 1	Argument involves a single claim with no grounds/ evidence or rebuttals.
Level 2	Argument involves claims with grounds/ evidence but no rebuttals.
Level 3	Argument involves claims or counterclaims with grounds/ evidence but only a single rebuttal.
Level 4	Argument involves multiple rebuttals challenging the claim but no rebuttals challenging the grounds (data, warrants and backings) supporting the claim.
Level 5	Arguments involve multiple rebuttals and at least one rebuttal challenging the grounds.
Level 6	Argument involves multiple rebuttals challenging the claims and grounds.

Note: The levels were modified after Erduran et al. (2004)

Although TAP is a very useful tool in science education enabling both educators and students to understand scientific argumentation, some researchers believe it has flaws. Willard (1976) asserts:

> When actually studying naturally occurring argumentation, the model [TAP] becomes problematic as it greatly limits the analyst's ability to consider the different perspectives in the discussion, the perspective of the speaker and that of the critical interlocutor. It does not suit the purpose of displaying how the speaker's arguments mutually influence and subtly transform the course of a discussion. (p. 312)

Willard (1976) maintains that TAP focuses too much on the protocol that it follow. Kneupper (1978) contends that Toulmin is critical of the disjuncture of formal logic and the practical concerns of "real life". His assertion is that Toulmin views non-logical phenomena as unimportant, because they based it on untestable facts. Furthermore, he believes that TAP cannot explain metaphysical experiences and concepts using "science of logic". Jegede (1995) and Ogunniyi (1995) support Kneupper's views and addresses the flaws of TAP, contributing to the formulation the Contiguity Argumentation Theory (CAT).

2.6.2 Contiguity Argumentation Theory (CAT). Jegede (1995) asserts that a student partially or totally accept what is taught in the science classroom (formal knowledge) and compare it with his everyday experiences (informal knowledge). The student can decide whether to keep the formal and informal knowledge separate or side-by-side. Jegede (1995) refer to it as "collateral learning" and Ogunniyi (1998) terms it "harmonious dualism", explaining how concepts like nature and nurture, predictable, unpredictable, physical and metaphysical, western science, and indigenous knowledge science can coexist in a mental state. Ogunniyi developed his theory of harmonious dualism further into the Contiguity Argumentation Theory CAT.

Ogunniyi's (2007a & b) CAT does not only explain deductive-inductive reasoning, but also metaphysical reasoning. The CAT is rooted in the Aristotelian Contiguity Theory (Afonso-Nhalevilo & Ogunniyi, 2011) which asserts that two states of mind tend to readily couple with each other to form an optimum cognitive state. A fundamental assumption of the CAT is that claims and counter claims on any subject matter or across fields (such as western science and indigenous knowledge) can only be justified if both systems of thought are initially accorded the same status until one is found to be inappropriate for a given context (Afonso & Ogunniyi, 2011; Ogunniyi, 2007a; Ogunniyi & Hewson, 2008). The CAT is a learning theory, which states that more than one distinct thought system can co-exist to create an optimum cognitive state. It recognizes five categories into which conceptions can move within an individual's mind or among individuals involved in dialogues justifying scientific and or metaphysical conceptions. These five categories exist in a dynamic state of flux in a person's mind, namely (Ogunniyi, 2007a):

- **Dominant mental state** – When it is the most adaptable to a given context for example, *living in a community where people strongly belief in witchcraft*.
- **Suppressed mental state** – When a more adaptable mental stage overpowers a dominant cognitive stage for example, *a religious person who becomes enlightened by scientific facts*.
- **Assimilated mental state** – When the dominant mental stage is absorbed into another more adaptable mental stage for example, *a Black person taking on customs of a White culture*.

- **Emergent cognitive stage** – When an individual has no previous knowledge of a given phenomenon, as would be the case with scientific concepts and theories for example, *atoms, gene, entropy, theory of relativity, etc*.
- **Equipollent mental state** – When two competing ideas or worldviews tend to co-exist in the mind of the individual, without necessarily resulting in a conflict for example, *a religious teacher teaching the evolution of man without any reference to his religion's bias.*

A dialogical argumentation pedagogy, interrogating formal knowledge and informal knowledge concepts within the framework of Ogunniyi's CAT, which considers the two types of knowledge as complimentary and equipollent, even though informal knowledge is situated within both evidence-based and metaphysical paradigms while formal knowledge is primarily empirical (Diwu, Ogunniyi & Langenhoven, 2011).

Toulmin's (1958) Argumentation Pattern (TAP) and the CAT are in agreement with socio-cultural constructivism as espoused by Vygotsky (1978) and personal constructivism as espoused by Piaget (1936). This study focuses more on Vygotsky's theory, emphasizing the role of the social environment in learning and cognitive development. In Vygotskian theory, a mediator assists thinking and action between the student and the environment, with the purpose of developing the student's cognitive capacity, which is critical in the dialogical argumentation process.

2.6.3 Dialogical Argumentation Instruction Model. Contiguity Argumentation Theory (CAT), Toulmin's Argumentation Pattern (TAP) and social constructivism form the foundation of the Dialogical Argumentation Instruction Model (DAIM), which is a pedagogical methodology creating discussion spaces within the classroom aligned to the learning objectives. The DAIM is one such model whereby an interactive teaching and learning process providing all participants with an opportunity to express their views in a non-threatening environment; the shared commitment is towards respectful presentation of opinions (Osborne, Simon & Collins, 2003). This approach allows spaces for dialectic exchanging of ideas and opinion to construct and enhance the understanding of science concepts. Kuhn (1992, 1993) supports the idea that the use of argumentative models in science education allows students to improve their cognitive and linguistic skills. He also believed that language is most important in developing higher cognitive functioning and allows a child to interact with other people by trading ideas. The educator mediates the learning process by using pedagogical models like argumentation to traverse the zone of proximal development (ZPD) (Collins, Brown & Newman, 1989; Erduran, 2006; Vygotsky, 1978).

Furthermore, argumentative models allow students to develop a better understanding of the role of argument and evidence in science, help them improve their communication and writing skills and strengthen their critical thinking skills and their ability to collaborate with others. Within the process of dialogical argumentation, the educator is encouraged to create a teaching and learning environment that provides an Inquiry-Based Science Education (IBSE) approach to understanding scientific concepts in the context of everyday lived and socio-cultural experiences. The intention is to create a meaningful student-centered approach by structuring thinking, writing, sharing, speaking and reflective spaces through the DAIM (Langenhoven & Ogunniyi, 2011).

The Science Indigenous Knowledge Systems Project (SIKSP) group, a research group that develops IKS-embedded instructional materials which high quality contextualized scientific material covering relevant topics of the CAPS from the Foundation to the FET phase, assisted in the development of DAIM. They combine IKS-embedded instructional tools with the requisite assessment materials that can act as benchmarks of quality, and exemplars for teaching, as a method of scaffolding instruction with the intention of creating dialogical spaces for science-IK argumentation lessons based on socio-scientific issues (Langenhoven, 2014). The model starts with an issue that has both indigenous knowledge and scientific knowledge viewpoints. The rationale is that students come from a home environment where they experience everyday knowledge and indigenous knowledge as ways of knowing. The conjecture is that these ways of knowing could be used to better resolve and understand contemporary issues and challenges in the sciences.

The first engagement is at the individual cognitive level (intra-argumentation) through guided questions, selected to stimulate critical thinking in the sciences. The next level is the sharing of ideas in a group (inter-argumentation) with the express purpose of reaching a group understanding of the issue. The group selects a representative to share the agreements and rebuttals raised within the group with the entire class (trans-argumentation). Once all the groups have presented, the facilitator manages a whole class discussion seeking trends and understanding of the issue by drawing on indigenous knowledge as well as scientific knowledge. The final stage is an individual and/ or focused group interview with selected participants on their understanding of the issue and processes taken to reach that understanding. Throughout the period, the role of the educator is not to interfere but to facilitate the process of dialogical argumentation by raising thought-provoking questions (Erduran, 2006; Langenhoven & Ogunniyi, 2011; Ogunniyi, 2004, 2007a & b, 2009a, 2011; Ogunniyi & Ogawa, 2008). Note that cognitive harmonization evolves continually at each step and the steps are cyclical in nature with opportunities for participants to reflect on their views and perceptions. Figure 2.2 illustrates the pedagogical schema model developed and piloted during the SIKSP seminars and workshops in 2009. The findings of the research group showed that different kinds of teaching and learning spaces emerged and that some educators lacked confidence and competence when using a dialogical argumentation-based teaching strategy in their lessons.

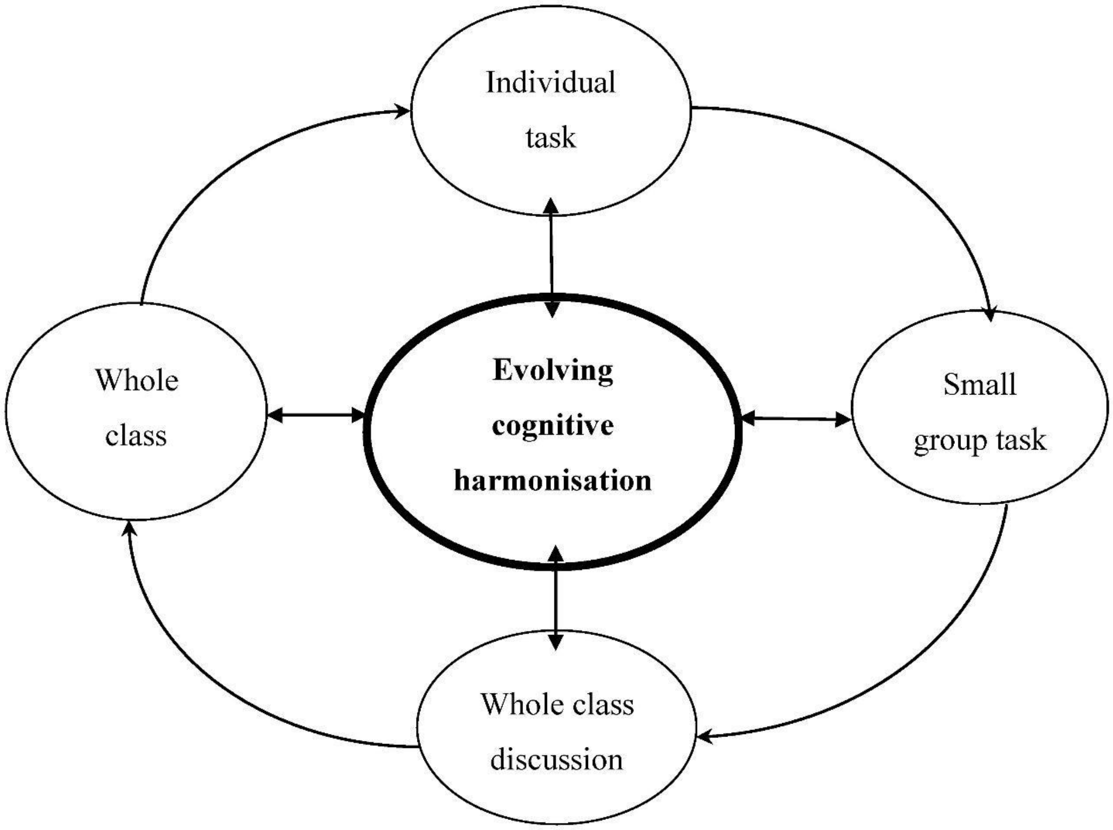

Figure 2.2: Pedagogical schema for implementing dialogical argumentation-based classroom discourses (Ogunniyi, 2007a)

The DAIM demands a form of argument, whereby participants are engaged in the type of argument, providing many opportunities to reach some consensus. This methodology encourages students to use argument as a tool for meaningful classroom discourse. It essentially motivates for arguments that result in meaningful learning through debates rather than arguing nonsensical points and deviating from the focus points. In my view, this instructional model could be very effective in the construction of knowledge, based on meaningful arguments, whose foci are reaching meaningful agreement based on valid evidence and justifiable reasons rather than wholesale absorption of pieces of information.

Thus, a stronger experiential-based learning with a research paradigm, using a mix of inductive, deductive and analogical pedagogies and argumentation-based material led to the DAIM illustrated in Figure 2.3. The DAIM comprises six stages that grow and expand as knowledge is constructed. The concept of the expanding shells in the figure is a form of visual modelling to show that knowledge grows and evolves as the educator and students move from one learning space to another.

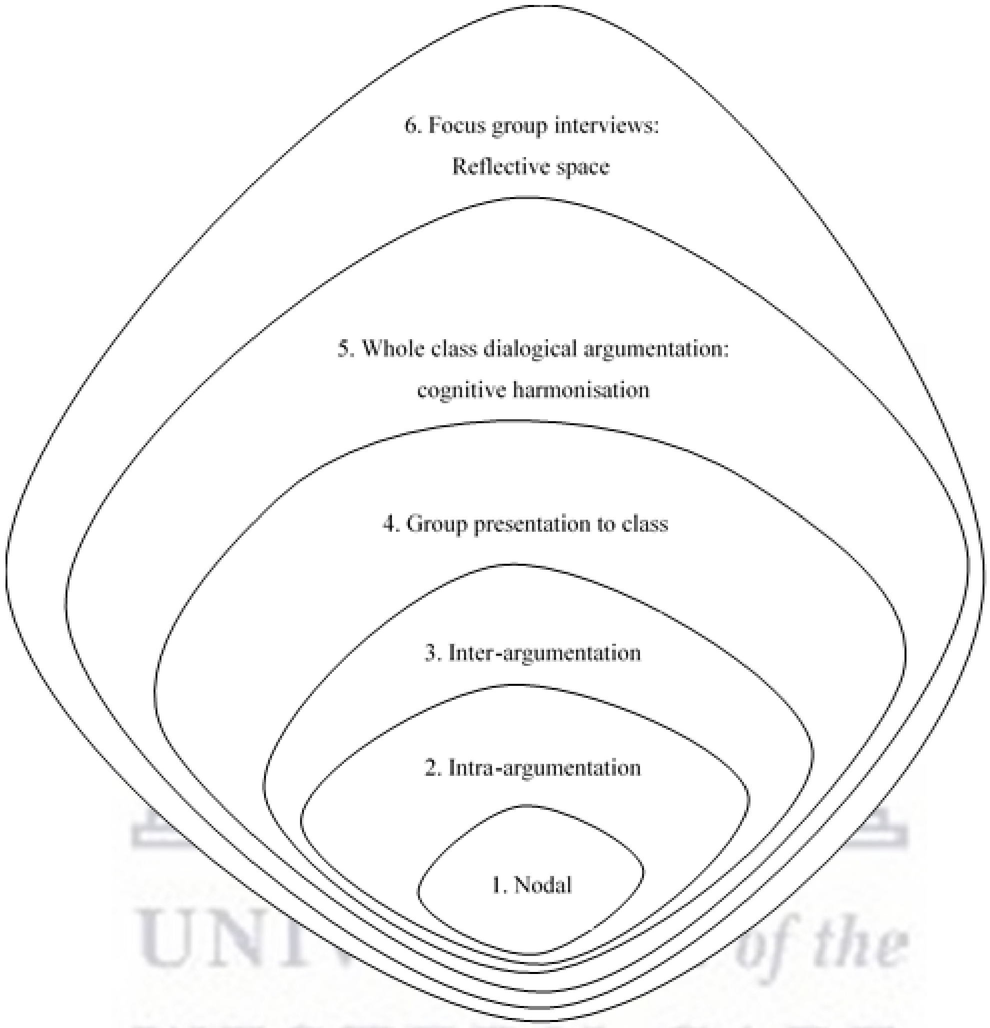

Figure 2.3: Dialogical Argumentation Instructional Model (Langenhoven & Kwofie, 2009, adapted from Ogunniyi, 2007a & b)

The six distinct growth stages of DAIM are:

Stage 1: *Nodal point* – The process starts with the selection of a socio-cultural scientific topic that includes some integrated science-indigenous knowledge concepts.

Stage 2: *Individual thinking space (Intra-dialogical argumentation)* – The individual student investigates/ enquiries/ considers the issue/ problem/ controversy/ concern as presented in the narrative. The individual is required to think about and formulate an opinion (claim) supported by reasons (evidence, data) in response to a series of questions. Students record their claims and reasons (grounds) in writing assisted by a writing frame report card. This step represents intra-dialogical argumentation since the conversation is with oneself. This thinking space is intentionally created, and facilitated by the educator.

Stage 3: *Small group sharing space (Inter-dialogical argumentation)* – Individuals share their views with other members of their small group of no more than five by engaging group members in debate, with the intention of establishing claims, counter-claims and rebuttals supported by grounds. The intention is to reach group consensus on an agreed point of view. This 'sharing space' also regarded as inter-dialogical argumentation occurs between participants in the group. The purpose is to reach a common group understanding of the issue under consideration and to give each member an opportunity to articulate his/ her opinion. In this way, students acquire a participatory voice in contributing to the argument or debate.

Stage 4: *Group presentation space (Trans-dialogical argumentation)* – Each group in the class selects a presenter who will share that group's point of view (claims and counter-claims, evidence and warrants) with the rest of the class. A text poster and an oral presentation provides the audio-visual stimulus for further discussion. The facilitator notes trends and thoughts that develop. The educator creates this 'presentation space' and chairs the follow-up class discussion in stage 5 by collating trends and emerging ideas.

Stage 5: *Whole class interpretive space (Meta-dialogical argumentation)* – Mediation by the facilitator (educator) is initiated and the entire class has an opportunity to contribute further arguments based on evidence (grounds, i.e. data supported by warrants, backings or qualifiers). Particular note of opposing claims or rebuttals recorded for later evaluation. The educator who acts as a co-constructor of the argument facilitates the whole class debate. This stage recognizes the participants' contribution to joint co-construction of knowledge and understanding through the identification of trends, themes and a meta-cognitive view about the issue under consideration. The objective is to use this 'interpretive space' to highlight disagreement and ultimately to reach a common understanding, consensus or viewpoint referred to as cognitive harmonization.

Stage 6: *Focused group reflective space* – The purpose of this stage is to create a space – called 'reflective space' – for dialogue with a selected small group in order to interrogate perceptions, viewpoints and experience with the DAIM methodology and the concepts presented in order to strengthen the consensus reached, and for students to voice any nagging concerns that may exist.

As the schema unfolds, knowledge evolves through co-construction involving both participants and facilitators, thus generating new perspectives and insights. The stages of DAIM are located within an ever-expanding (shell) structure that symbolizes the evolving nature and construction of knowledge acquired by participants. TAP is used to rate the level at which dialogical argumentation occurs within groups while the CAT is used to reconcile conflicting schemata between common sense and anthropomorphic worldviews with the mechanistic, empirical and counter-intuitive views embedded in the nature of science with respect to school science (Ogunniyi, 1995; 2004; 2009a; Langenhoven, 2009).

Diwu (2010) found that students exposed to DAIM in a science classroom significantly outperformed a comparable group of students receiving traditionally expository instruction. He also found that the students received this argumentation-based instruction as a "much easier" way to learn science. In the research of Langenhoven (2014), the pre-service science educators commented that DAIM is a workable method for fostering growth, thinking, debating skills, confidence building and a socializing agent. Several research studies with similar findings suggesting that DAIM could be an effective methodology in the science classroom (Angaama, 2012; Philander, 2012; Riffel, 2013; George, 2014; Hlazo, 2014; Goodman, 2015; February, 2016; Iwuanganwa, 2017; Magaseti, 2017). Although the significant positive findings of research based on the impact of DAIM on teaching and learning of science are a noticeable, there appear to be a critical flaw in DAIM. It is obvious that feedback and review processes form part of DAIM; however, intentional and explicit formative assessment strategies for responsive teaching are absent. This study therefore investigates assessment for learning as an addition to DAIM pedagogy.

2.7 Assessment

An explosion of developments in assessment took place in the post-democracy (1994) era in South African Education Policy where a number of key actors re-conceptualized the role of educational assessment (Gipps, 1994). The term 'assessment' often used in different contexts, means different things to different people. The Department of Education generally refer to assessment as a process of making decisions about a learner's academic performance (South Africa, Department of Education, 2006). Black and William (2010) define assessment as all those activities undertaken by teachers and their learners when assessing themselves, whereby critical feedback provides constructive response. Shepard (2000) provides a more comprehensive description of assessment:

> It is an ongoing process aimed at understanding and improving student learning. It involves making the expectations explicit and public; setting appropriate criteria and high standards for learning quality; systematically gathering, analyzing, and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document, explain, and improve performance. (p.69)

Many educators think of assessment in terms of testing and grading: scoring quizzes and examinations, and assigning course grades to students. They typically use assessment as a way to inform students about how well they are doing or how well they did in the courses taught. An emerging vision of assessment is that of a dynamic process that continuously yields information about student progress toward the achievement of learning goals. This vision of assessment acknowledges that when the information gathered is consistent with learning goals and used appropriately to inform instruction, it can enhance student learning. Therefore, it should not be viewed separately from instruction and not just the culmination of instruction assessment, but seen as an integral part of teaching and learning, (Garfield, 1994).

Instruction, learning and assessment are intricately linked classroom processes (Gipps, 1994). The 'boxed' part of Figure 2.4 shows two main uses of assessment, namely formative assessment and summative assessment, in relation to students' learning and the assessment models used for the context of this study. The assessment continuum varies from assessment for learning (AfL) to assessment of learning (AoL) with Assessment through Learning (AtL) at the center. The functions of all modes of assessment should contribute and result in Assessment of Learning – summative assessment.

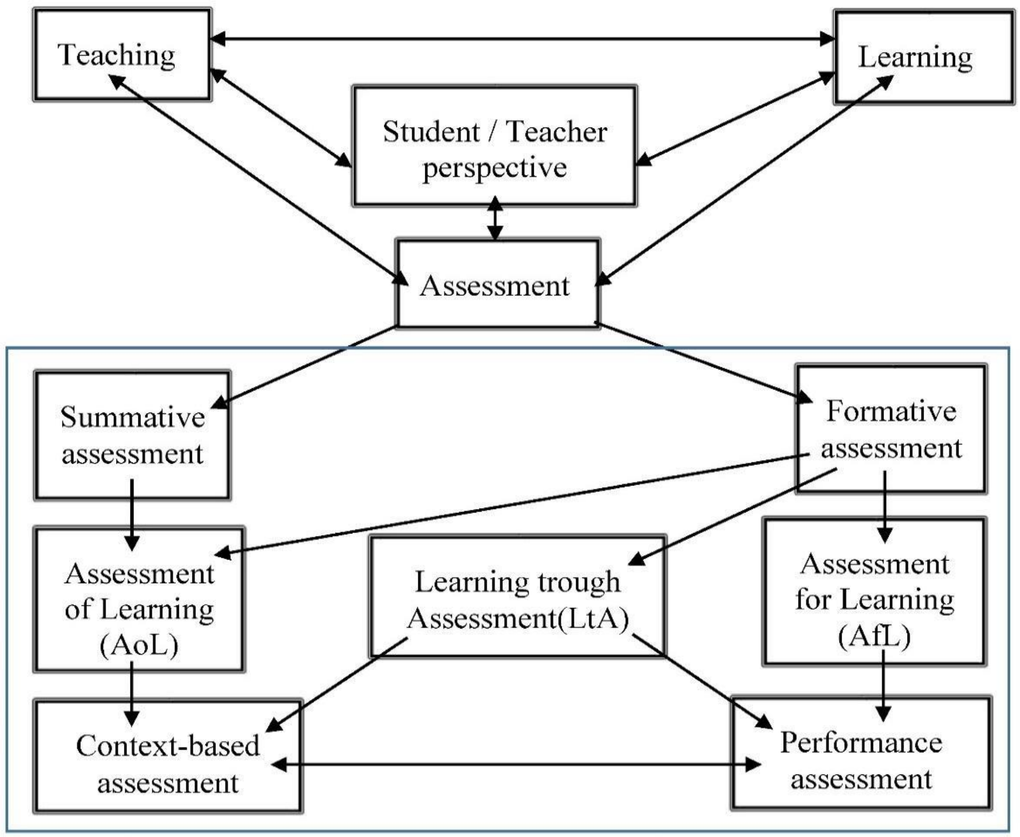

Figure 2.4: Relationships between different components of assessment (Kelly, 2007)

Gregory, Cameron and Davies (1997) outlined some distinct differences between AfL and AoL. Educators are using these terms to help distinguish between the teacher's role as a learning coach (AfL) and the teacher's role of judging (AoL) the extent of a student's achievement in relation to an established standard. AoL is considered a mode of summative assessment, completed at the end of a learning process. Gregory et al. (1997) contrast the two types of assessment as 'the big deal' versus 'the done deal', supportive learning versus learning measures, learning using descriptions versus learning using scores, and learning happening moment by moment versus learning happening at the end. However, they point out that neither type is better than the other, but both need to be used within a student's learning so that the student is able to understand not only the work that is required of them, but also how their own learning occurs.

My observation is that, the dominant role of summative assessment continues at the TVET colleges to be one of competition and control, rather than of motivation and enabling learning to take place. However, at the heart of effective teaching is formative assessment focusing on diagnosis and improvement of learning efforts (Black & Wiliam, 2009).

2.8 Formative assessment

In the analogy of Black and Wiliam (2009) in which they compare the education system to engineering systems:

> The classroom is a black box in which certain inputs from the outside — pupils, teachers, other resources, management rules and requirements, parental anxieties, standards, tests with high stakes, and so on — fed into the box. Some outputs are supposed to follow pupils who are more knowledgeable and competent, better test results, teachers who are reasonably satisfied, and so on. However, what is happening inside the box? How can anyone be sure that a particular set of new inputs will produce better outputs if we don't at least study what happens inside? (p. 81)

This analogy implies that most of the reform initiatives, e.g. C2005 to CAPS, do not give direct help and support to the work of teachers in classrooms. Therefore, it is up to the teachers to make it work inside the box, by being innovative and employing formative classroom activities. Formative assessment itself is nothing new and effective teaching depends mainly on adapting the teaching methodology by taking into account the positive aspects of previous teaching experiences. These adaptations are dependent on various variables such as class size, pace of learning, subject content, etc. At one extreme, an educator explaining something to an individual student may amend his/ her approach almost instantaneously in response to a frown of puzzlement on the student's face or some other aspect of body language. The adaptations may occur in teaching situations with just as narrow a focus over a much longer time scale. For example, when a science teacher finds that a particular methodology to teach the concept of mechanical gears is effective for students familiar to components of machines, but that methodology is ineffective for students who never saw an engine. In the latter, teach must have a narrow focus over a longer time scale. Conversely, when teaching a whole class, many educators use a 'reference group' of students (Dahllof, 1971) to judge the pacing of their lessons (broader focus, short time scale). At the other extreme, an adaptation can have both a broad scope and take place over a long time scale, as in the case of the C2005 to CAPS curriculum review process in South Africa.

Hargreaves (2017) conducted a survey with 83 teachers and head-teachers to determine their conception of formative assessment. She summarised the responses of the teachers into the following six definitions:

- Assessment for learning means monitoring students' performance against targets or objectives.
- Assessment for learning means using assessment to inform next steps in teaching and learning.
- Assessment for learning means teachers giving feedback for improvement.
- Assessment for learning means [teachers] learning about what students learning.
- Assessment for learning means children taking some control of their own learning and assessment.
- Assessment for learning defined as turning assessment into a learning event.

The common element in these responses is that of feedback. Ramaprasad (1978) concur with this conclusion and explain formative assessment as "obtaining and acting on information about the gap between the actual level and the reference level of a system parameter which is used to alter the gap in some way" (p. 4). This notion corresponds with the scaffolding process in the zone of proximal development of the constructivist theory of Vygotsky (1978). Furthermore, Sadler (1989) asserts:

> An important feature of Ramaprasad's definition is that information about the gap between actual and reference levels is considered as feedback only when it is used to alter the gap. If the information is simply recorded, passed to a third party who lacks either the knowledge or the power to change the outcome, or is too deeply coded [for example, as a summary grade given by the educator] to lead to appropriate action, the

> control loop cannot be closed, and "dangling data" is substituted for effective feedback. (p. 121)

However, Sadler make us aware that not all feedback is benefiting the students; the 'dangling data' make feedback useless. Formative assessment and feedback can help students take control of their own learning and become self-regulated learners. In many instances, students are already assessing their own work and generating their own feedback, which is important for learning. I am of the view that there should be a shift in focus, seeing students having a proactive rather than a reactive role in generating and using feedback. This will have profound implications for the way in which educators organize assessments and support learning. Butler and Winne (1995: p.246) support this notion, asserting that: "… the most effective students are self-regulating". These students are aware of the quality of their own knowledge, beliefs, motivation and cognitive processing. Figure 2.5 presents a conceptual model of self-regulation and feedback, based on the work of Butler and Winne, that synthesises self-regulating learning and feedback. The shaded area depicts processes internal to the student, showing how the student monitors and regulates learning and performance. It also shows the crucial role of internally generated feedback in these processes (Nicol & Farlane-Dick, 2006). Pintrich and Zusho provide the following working definition of self-regulation:

> Self-regulated learning is an active constructive process whereby students set goals for their learning and monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features of the environment. (2002, p. 64)

This definition fits the purpose of this study and agreeing with Vygotsky's (1978) constructivist theory as it recognizes that self-regulation applies not just to cognition, but also to motivational beliefs and overt behaviour. It also recognizes the limits to student self-regulation, for example, the educator usually devises the learning task and determines the assessment requirements.

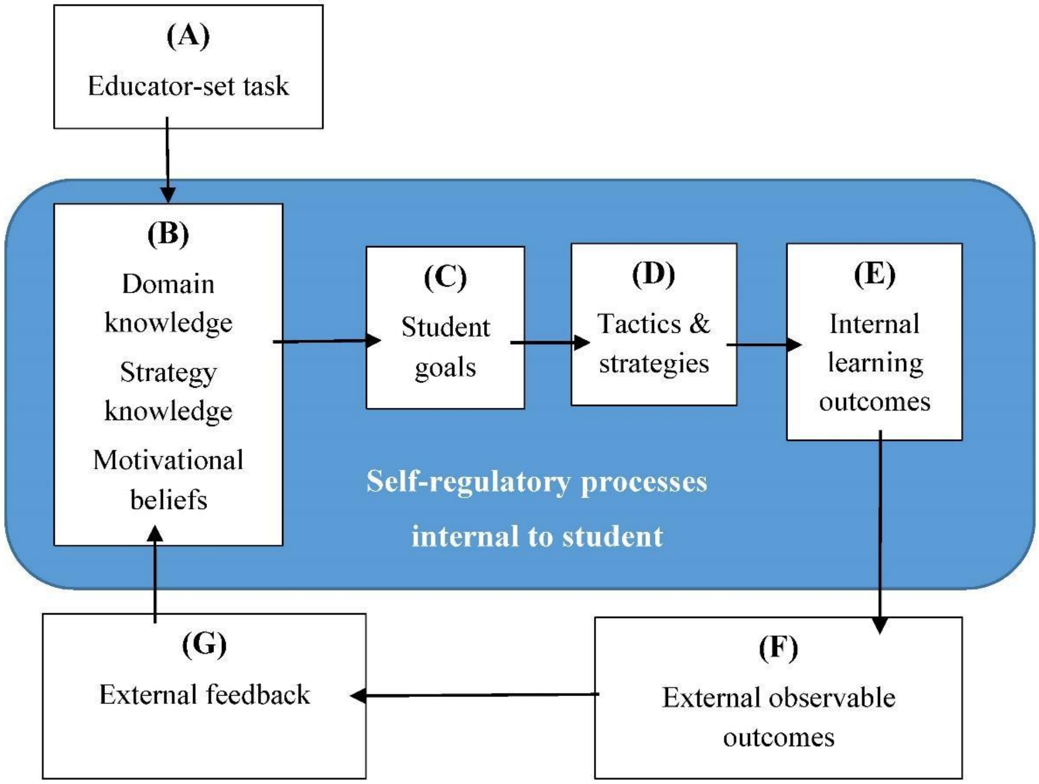

Figure 2.5: Model of self-regulated learning and feedback (Nicol & Farlane-Dick, 2006)

In the model, an academic task set by the educator (A) in class or set as an assignment shown as the trigger to initiate self-regulatory processes in the student. Engagement with the task requires that the student draws on prior knowledge and motivational beliefs (B) and constructs a personal interpretation of the meaning of the task and its requirements. Based on this internal conception, the student formulates his/ her own task goals (C). While there would normally be an overlap between the student's goals and those of the educator, the degree of overlap may not be high (e.g. if the student wishes only to pass the assignment). The student's goals might also be fuzzy rather than clear (e.g. a vague intention or task orientation). Nonetheless, these goals would help shape the strategies and tactics (D) used by students to generate outcomes: both internal (E) and external (F) observable outcomes. Internal outcomes refer to changes in cognitive or affective/ motivational states that occur during task engagement (e.g. increased understanding or changes in self-perception of ability). External observable outcomes refer to tangible products (e.g. essays) and behaviours (e.g. student presentations).

Monitoring these interactions with the task and the outcomes produced cumulatively generates internal feedback at a variety of levels (i.e. cognitive, motivational and behavioural). This feedback derived from comparing current progress against desired goals to help the student determine whether current modes of engagement should continue as is or if some type of change is necessary. For example, this self-generated feedback might lead to a re-interpretation of the task or to an adjustment of internal goals or of tactics and strategies. The student might even revise his/ her domain knowledge or motivational beliefs, therefore influencing subsequent self-regulation.

In the model, the educator, a peer or other means provide external feedback to the student (G). This additional information might augment, concur or conflict with the student's interpretation of the task and the path of learning – formative assessment. However, to produce an effect on internal processes or external outcomes the student must actively engage with these external inputs. In effect, the interpretation of the educator's feedback responses influences the construction and conception process of the student significantly and subsequent learning (Ivanic, Clark & Rimmershaw, 2000).

The self-regulation model and research literature on formative assessment (Rosenshine, 2012) identified some principles of good feedback practice. Nicol and Farlane-Dick (2006) define good feedback practice as "… anything that might strengthen the students' capacity to self-regulate their own performance". After they synthesized research literature on feedback, they produced the following seven principles, which resonate with the Dialogical Argumentation Instruction Model:

1. Helps clarify what good performance is (goals, criteria, expected standards) – **nodal point**.
2. Facilitates the development of self-assessment (reflection) in learning – **intra-argumentation**.
3. Delivers high-quality information to students about their learning – **inter and trans-argumentation**.
4. Encourages educator and peer dialogue around learning – **inter and trans-argumentation**.

5. Encourages positive motivational beliefs and self-esteem – **nodal point**.
6. Provides opportunities to close the gap between current and desired performance – **inter and trans-argumentation**.
7. Provides information to educators that help shape the teaching process – **reflective space**.

There is considerable research evidence showing that effective feedback leads to learning gains (Black & Wiliam, 2009; Gipps, 1994; Nicol & Farlane-Dick, 2006). Black and Wiliam (2010) drew together over 250 studies of feedback carried out since 1988 spanning all educational sectors. These studies focused on real teaching situations and the selection included educator-made assessments, self- and peer assessments. A meta-analysis of these studies revealed that feedback produces significant benefits in learning and achievement across all content areas, knowledge and skill types, and levels of education. Hattie (1987), Crooks (1988) and Black & Wiliam's (2010) reviews provide convincing evidence of the value of feedback in promoting learning. In addition, there is a large body of complementary research studies demonstrating the effects of self and peer feedback on learning (e.g. Boud, 1995; Boud, Cohen & Sampson, 1999). Nonetheless, while the work of Black and others have had an important influence on teaching practices in schools (Black et al., 2003) they have so far had much less influence on higher education.

One of the most influential papers underpinning the Black and Wiliam (2010) review and the writings of other researchers (e.g. Yorke, 2003) is that of Sadler (1989), identifying three conditions necessary for students to benefit from feedback in academic tasks. He argues that the student must know:

1. What is good performance? – must possess a concept of the goal or standard being aimed for.
2. How current performance relates to good performance – students must be able to compare current and good performance.
3. How to act to close the gap between current and good performance.

From this analysis, Sadler (1989, p. 115) makes an important observation, “For students to be able to compare actual performance with a standard and take action to close the gap, then they must already possess some of the same evaluative skills as their teacher”.

Therefore, in order to improve the quality of feedback responses, educators should focus much more effort on strengthening the skills of self-assessment in their students (Yorke, 2003; Boud, 2000).

2.8.1 Assessment for learning (AfL). The word ‘assessment’ often leads to confusion, because some educators conveniently disregard the formative elements of assessment when referring to summative testing. They performed exactly what they believe to be effective in the formative assessment to support their teaching activities. However, when talking about the implementation of formative assessment, they often start their responses referring to policy, rules and regulations. This is an evidence that educators are influenced by bureaucracy because lecturers have read and learned by heart the regulations of the education department (Tien, 2020). Does this hinder the implementation process of formative assessment?

Intricately linked formative assessment and classroom instruction perform the similar functions and have the same objectives. Many researchers also use formative assessment interchangeable with the term assessment for learning (AfL). Black and Wiliam (2010) proposed creative or innovative instruction instead of formative assessment to avoid confusion.

a) Closing the gap. Traditionally, assessment for learning (AfL) has been closely associated with formative assessment because practices such as questioning and providing feedback help ‘form’ or ‘shape’ student learning. This differs from summative assessment, which typically is an attempt to measure student attainment at the end of a period of learning. Figure 2.6 classifies the nature of different types of formative and summative assessment as either formal or informal.

	Formative Assessment	Summative Assessment
Informal	Questioning Feedback Peer assessment Self-assessment	Essays in uncontrolled conditions Portfolios Coursework Teacher assessment
Formal	Further analysis or tests, exams, essays Target setting	Tests Exams Essays in controlled conditions

Figure 2.6: Classification of assessment (Gipps, 1994)

Assessment for learning (AfL) mainly focuses on the use of informal formative assessment to improve learning, however, formal summative tests can also be used for formative assessment. Assessment for learning is also an approach to teaching and learning that creates feedback used to improve students' performance. Students become more involved in the learning process and gain confidence in what they learn and to what standard.

It can be argued that all of the assessment strategies in Figure 2.4 support AfL if their ultimate use is to help the students' progress in terms of their learning. A good example of using a summative assessment strategy in an AfL context is where a test or exam is used to identify a lack of understanding (e.g. in a particular area of the syllabus) and subsequently targets are set to rectify this. "In assessment for learning, it is the purpose of assessment, rather than the nature of it, that is important" (Dweck, 2017: p.24). Carol Dweck (2017) contends that there are five main processes that take place in AfL:

1. Questioning enables students, with the help of their educator, to determine the nature of conception in terms of understanding a specific concept. For example, whether a concept is emergent (new) to a student, a student has a misconception about or mastered the concept.
2. The educator provides feedback to each student about how to improve his or her learning.
3. Students understand what successful work looks like for each task they are doing.

4. Students become more independent in their learning, taking part in peer assessment and self-assessment.
5. Summative assessments used formatively help students to improve.

Wiggins and McTighe (1998) are of the opinion that formative assessment is directly linked to backward design planning, asserting that if learning was to be effective for the students, the educator must begin with the final destination in mind. Designing curricula in this way has been described as backward design planning (also referred to as 'Understanding by Design') because educators start with the big ideas or goals they want the students to master, rather than starting with traditional curriculum planning and interesting activities and textbooks in mind (Wiggins & McTighe, 1998).

This approach is in line with Toulmin's Argumentation Theory, which requires one to have the necessary data before one can make a claim. Educators should be clear about what learning targets or goals set for the students and what formative assessments used to provide evidence that the students have mastered those targets or goals. The students need to be aware upfront of what the assessments will be along the way for the culmination; so that they have a clear sense of what goals, they need to meet. When students know the reasons for each assessment, they will understand what is being asked of them and when (Wiggins & McTighe, 1998). Covey (1990, p.51) asserts that, "To begin with the end in mind means to start with a clear understanding of your destination".

Educators begin with the end in mind and set the task to reflect the learning. Therefore, they should inform the students about the big ideas and essential questions, the performance requirements and the evaluative criteria at the beginning of the unit or course. The students should be able to describe the goals (big ideas and essential questions) of the unit or course. This will help to ensure that the students are aware of the expectations and optimal learning takes place. Figure 2.7 illustrates the sequence of backward design learning. This approach requires an equally clear understanding of the point of departure (where you are now) so that the steps taken are always in the right direction. For example, (1) desired outcome for a lesson could be - 'Students will understand the concept of moments', (2) evidence of learning - 'students must be able to apply the law of moments to balance a horizontal beam' and (3) curriculum and instruction – 'build a zig saw model balancing weights'.

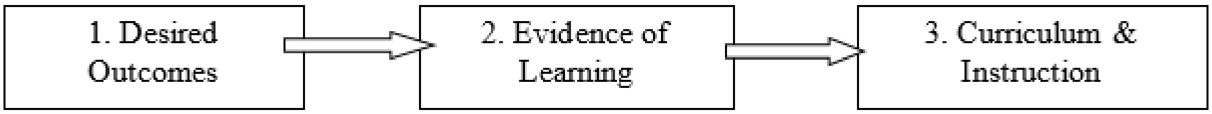

Figure 2.7: Backward design learning

Wiggins and McTighe (1998) argue that backward design focuses primarily on student learning and understanding, because teachers are designing the lessons, units, or courses, they focus on the activities and instruction rather than the outputs of the instruction. This feature of backward design is a crucial part of assessment for learning. Furthermore, it could be essential in the planning of AfL activities which aims to 'close the gap' between students' current situation and where they want to be in their learning and achievement, as illustrated in Figure 2.8. Skilled educators plan tasks, which help students to do this. AfL involves students becoming more active in their learning and starting to think like an educator and to think more actively about where they are, where they are going and how to get there.

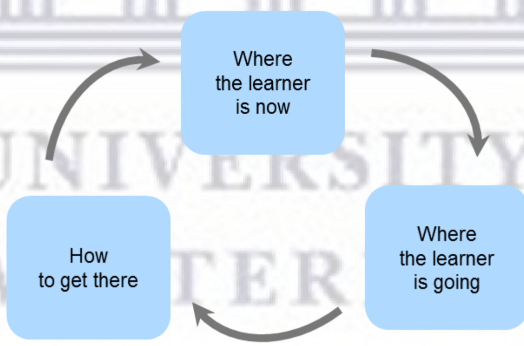

Figure 2.8: Closing the gap (Moss & Brookhart, 2019)

b) Unifying formative assessment. All the AfL strategies try to close the conceptual gap between 'where students are now' and 'where students are going' and this can only happen through innovative and formative interactions in the classroom. In their research to develop formative assessment into a theory Black and Wiliam (2010) concluded that improved formative assessment helps low achievers more than other students, reducing the range of achievement while raising achievement overall (effect-size ranges from 0.4 to 0.7). AfL focuses on engaging students in classroom assessment, supporting their own learning and informing educators what to do next in assisting students to progress. AfL is assessment for improvement not assessment for accountability, as can be the case with summative assessments (Stiggins, 2002). The key to AfL is to use a variety of assessment tools and methods in order to provide ongoing evidence to students, educators and parents that demonstrates how well each student is mastering the identified outcomes. The evidence used to provide descriptive feedback to the students, enabling the educator to differentiate the instruction and meet the needs of individual students or groups.

Cooper (2007) defines AfL as, "assessment designed primarily to promote learning. Early drafts, first tries, and practice assignments are all examples of assessment for learning". Cooper also asserts that AfL determines student achievement at a given point in time. He strongly advocates that report card grades should be composed of data from assessments of learning. Cooper (2007) highlights the 'Eight Big Ideas' that an educator should be aware of when practicing AfL:

Big Idea 1: Assessment serves different purposes at different times.

Big Idea 2: Assessment must be planned and purposeful.

Big Idea 3: Assessment must be balanced, including oral, performance and written tasks and is flexible in order to improve learning for all students.

Big Idea 4: Assessment and instruction are inseparable because effective assessment informs learning.

Big Idea 5: For assessment to be helpful to students, it must inform them in words (not numerical scores or letter grades) what they have done well, what they have done poorly, and what they need to do next in order to improve.

Big Idea 6: Assessment is a collaborative process that is most effective when it involves self- assessment, peer assessment and educator assessment.

Big Idea 7: Performance standards are an essential component of effective assessment.

Big Idea 8: Grading and reporting student achievement is a caring, sensitive process that requires educators' professional judgement.

Black and Wiliam (2009) developed the 'Eight Big Ideas' for Assessment for Learning of Cooper further, producing to the 'Six Big Strategies' for AfL:

Strategy 1- Providing students with clarity about objectives. Understanding of the learning intentions of the work done. (The educator presents students with the learning intentions at the beginning of the lesson, throughout the lesson, and refer to the learning intentions in their reflections and responses so teachers can see that connections between tasks and what is supposed to be learned are made) – *This strategy corresponds with the nodal point of the DIAM and the first step of backward design.*

Strategy 2- Providing to and co-developing the criteria for success with students (what will the finished task look like, how will you share your understanding with others?) – *The nodal point of DAIM and the second step of backward design*.

Strategy 3- Providing ongoing descriptive feedback that moves learning forward for each student (using feed forward in language the students understand; how can the next task improve upon the previous?) – *The reflective space of DAIM*.

Strategy 4- Designing and using thoughtful classroom questions to lead discussions that generate evidence of learning (allowing the students to participate and interact among each other in meaningful oral discussion – talk is student to student(s), not a dialogue between the educator and one student) – *the inter-argumentation space of DAIM.*

Strategy 5- Putting students to work as learning/ teaching resources for each other using self-assessment and peer assessment (student coaching, students understanding learning intentions so well that they can teach a younger student or peer) – *the inter- and intra-argumentation spaces of DAIM and the scaffolding process in the ZDP*.

Strategy 6- Doing everything we can think of to ensure that students have ownership of their own learning (empowering each student to succeed) – *ownership.*

These six AfL strategies should be part of the lesson planning of any educator in order to improve student participation and interaction. In order to provide a better theoretical grounding for formative assessment, Thompson and Wiliam (2007) drew on Ramaprasad's (1983) three key processes in learning and teaching:

- Establishing where the learners are in their learning.
- Establishing where they are going.
- Establishing what needs to get them there.

Thompson ad Wiliam (2007) produced a unifying basis for the diverse practices of formative assessment, illustrated in Figure 2.9. They crossed the three processes, which also correspond with 'closing the gap', with the different agents (teacher, peer, learner) in the classroom.

Agent	Where the learner is going?	Where the learner is now?	How to get there
Teacher	(1) Clarifying learning intentions & criteria of success	(2) Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding	(3) Providing feedback that moves learners forward
Peer	Understanding and sharing learning intentions & criteria of success	(4) Activating students as instructional resources for one another	
Learner	Understanding learning intentions & criteria of success	(5) Activating students as the owners of their own learning	

Figure 2.9: Unifying framework of formative assessment (Black & Wiliam, 2009)

Traditionally, the teacher takes responsible for each of the three key processes to close the gap. It is also necessary to take account of the role that the learners and their peers play. Furthermore, since the responsibility for learning rests with both the educator and the student, it is incumbent on each to do all they can to mitigate the impact of any failures of the other, therefore, educators and students are jointly and severally liable.

c) Benefits of AfL in the classroom. Effective formative assessment strategies are very important contributors to success in summative assessment. This it gives students a clear idea what the outcomes are and what they need to do to achieve them. AfL increases confidence and helps create a sense of self-efficacy - a student's confidence in their ability to reach targets through hard work and determination (Ketter & Hunter, 1997). This is an essential quality for students to develop. Self-efficacy will help them succeed throughout their lives, both professionally and personally. On the other hand, students receiving poor grades and bad comments in a test may withdraw from learning might be perceived to be 'lazy' and 'stupid'. However, an AfL approach give students task-specific feedback, focusing on the work rather than ego-specific feedback. This encourages students to feel that they can improve their performance. Furthermore, AfL techniques such as peer feedback can help more-able students to reinforce their learning by explaining ideas to less able students. Therefore, peer feedback helps students to develop diplomacy and communication skills that will be essential in many aspects of later life.

Another advantage of AfL is, enabling students to become active participants in the classroom, especially when combined with other methods promoting self-regulated learning. Students will develop the skill of self-assessment, ownership of the learning process; and increase their sense of confidence, responsibility and creativity. In addition, educators have more time reflecting on the learning progress to plan what should follow next. Carol Dweck (2017) argues that high-achieving students avoid taking risks because they are afraid of making mistakes and this reduces the amount they can learn. However, AfL helps to create a supportive and cooperative classroom in which everyone, including the educator, should feel able to try new things without worrying that they might fail. I believe that, if the educator presents mistakes as opportunities for learning, this would help every student to reach their full potential. Students will start to see that they can improve outcomes in the future, learning from their mistakes.

There might be concerns that using AfL might cause chaos in the classroom when discussing work. This will naturally involve some talking and, inevitably, some noise. However, the educator remains in control and decides when to let the class talk and when to ask them to be quiet. McKinney and Graham-Buxton's (1993) research shows, working with peers in heterogeneous learning groups leads to positive educational outcomes. They argue that the misconception that peer-feedback means students chatting to each other aimlessly, rather than working on a task is false. Effective peer-feedback can only take place when students have a clear idea about the areas that they should (and should not) be giving feedback on. Students should also think about and understand how they are judging each other's work. The more students engage with and think deeply about the success criteria, the more they are able to give useful feedback to their peers (McKinney & Graham-Buxton, 1993).

In order to get the buy-in of management and/ or educators at school or college could be very challenging. It sometimes will require professional training and a paradigm shift for stakeholders in the teaching and learning process. However, the unifying framework proposed by Black and Wiliam (2009) provides a useful basis to plan for effective implementation of formative assessment practices in the classroom. The most important element of the framework is the role players inside the 'black box'.

2.8.2 Assessment for learning activities. Formative assessment activities play a valuable role in the all-round education of students, whether in problem-based learning, team projects or in the more traditional academic scenario of the tutorial or seminar. AfL emphasizes the creation of a student-centered classroom with a supportive atmosphere, allowing students to make mistakes and to learn from them. Generally various formative assessment strategies are implicitly embedded in instruction methodologies, however, it is important that educators should employ these strategies explicitly and intentionally to enhance the learning in the classroom. These activities can also develop the more instrumental skills of listening, presenting ideas, persuading, and working as part of a team. Most importantly, AfL activities in small groups should give students the chance to monitor their own learning, thus gain a degree of self-regulation and independence in their learning. The understanding and appropriate use of AfL strategies is crucial for educators in order to apply the unifying framework of Wiliam and Thompson (2007). Some specific practical activities are entry and exit tickets, show and tell, fishbowl, think-alouds, think-pair-share, buzz groups, circle of voices, rotating trios, snowball, jigsaw, learning teams, thumbs up/ down and focused interviews (Brookfield & Preskill, 1999; Jaques, 2000; Silberman, 1996). These activities could be used in the following, more general AfL strategies:

a) Questioning. Questioning is a quick and important way of finding out what a student understands about a subject. Questions should grab the attention of students and encourage them to ask questions. Black and Wiliam assert that:

> The key feature [of questioning] is that the teacher finds ways of helping the student to be active in the classroom, and helping the student to speak out and express their ideas. Until that happens, the teacher does not know what the students need. (2009: p.7)

The two main types of questions are closed and open questions. A closed question requires a short answer, such as remembering a fact, for example, 'What is the SI-unit of energy?' The answer is usually right or wrong. Rowe (1987) found that, on average, educators only wait 1.7 seconds after asking a question before taking an answer from a student. She suggests that increasing 'wait time' to three seconds improves the quality of answers. One way to help increase 'wait time', and to ensure the whole class is actively engaged, is to ask your students to write down the answer to a closed question on a piece of paper, mini-whiteboard or tablet, and hold it up. This immediately gives you feedback about who understands, who does not, and what the next steps in the learning might be. In an AfL classroom, finding out what students do not know is as valuable as finding out what they do know. This knowledge helps the educator to see what material the students need to spend extra time on to ensure that they all understand.

Open questions need longer answers and often require the students to provide an opinion. For example, 'What will happen to the flow of water through a hose pipe if a smaller nozzle is fitted to it? Explain how this relates to the study of voltage, current and resistance in a simple electric circuit'. Open questions like this allow all students to try to answer the question and be part of a discussion. The educator can then facilitate the discussion and ask questions to develop the discussion, which makes it conducive for dialogical argumentation. Dialogic teaching takes place when there is ongoing talk between educators and students, which leads to effective learning. This type of teaching gives a clearer view of what understanding and misunderstandings the students have about a topic.

Besides the fact that educators need to know how to use open and close questions skillfully, questions need to be probing and assess the different knowledge levels of students. Bloom's taxonomy is a very useful tool to assist educators and students to acquire the skill to use questioning for deep learning, section 2.8.3 below elaborates this more fully.

b) Feedback. During this process, students come together with their educators to discuss where they are in their learning, where they want to be in their learning and how they are going to get there. Moss and Brookhart (2019) assert that feedback is the 'bridge' between teaching and learning – closing the knowledge gap. It usually involves looking at a particular piece of work done by the student, understanding the aims and objectives of any assignment. Providing 'success criteria' before students start work can be helpful. Feedback might involve marking. However, a student may only remember the mark/ grade and not act on any comments to improve their work. In an AfL classroom, an educator should give 'comment only' feedback on their students' work and if a grade is required, it should be given later on (Black & Wiliam, 2010). This means students are able to read the comments of the educator before receiving the grade. Effective feedback depends on task-focused comments, rather than ego-focused comments. For example, a comment like, 'Great work Melanie, you are the top learner in the class!' could make strong students complacent, thinking that they do not have anything to do to improve.

c) Peer assessment. In this process, students assess each other's work and give each other feedback for example, think-pair-and-share and group work activities. This feedback gives an understanding of what makes a successful piece of work. The educator is vital to this process, as educators know their students and can help them to develop critical and reflective thinking skills (Kelly, 2007). By giving students freedom and control during group work activities are good opportunities ways to take responsibility for their own learning. Peer feedback also helps students to develop their social skills and to use higher-level skills such as thinking critically and analytically. A successful peer feedback session requires students to 'think like an educator' for each other. Each student will apply the success criteria to another students' work, and make value judgements based on these. The student then has to give the partner ideas for how to improve the work. In doing this, they will both increase their understanding of what makes a successful piece of work.

d) Self-assessment. In self-assessment, students evaluate their own work and think about their own learning. This helps them to make sense of what the educator says, relate it to previous learning and use this for new learning. Ultimately, self-assessment enables students to set their own learning goals and be responsible for their own learning (Black & Wiliam, 2010). However, students cannot become reflective students overnight. It takes time and practice to develop these skills, and the role of the educator is crucial in encouraging this.

e) The formative use of tests and exams. Summative assessment is a very important part of the education process. Therefore, the formative use of tests and examinations maximise learning gains (Rosenshine, 2012). Educators could return marked test or examination papers to students so that they can spend time understanding where they earned most marks and where they had misunderstandings. After the examination or test, educators should find out which questions students struggle with, giving the educator important information about what subjects, ideas and skills students need to work on. The educator can then focus on explaining the areas of the syllabus that gave problems to most of the students. Students could also work through examination questions in class in pairs or groups as a peer-learning activity.

f) Creating an AfL atmosphere. It is important to encourage an atmosphere of mutual supportiveness in the classroom, because students need to be relaxed and feel free to interact. It is helpful to explain to students why peer feedback is used and how they are going to benefit from it (Black & Wiliam, 2010). A good practice is to start a peer feedback session with an in-depth discussion of success criteria. Educators should share examples of successful work from previous years with the students. The educator should know when and how to divide students into small groups or pairs.

g) Criteria-reference rubric. South African higher education policy has been moving towards the adoption of criterion-referenced assessment according to Outcomes-Based Education and an increased focus on constructivist approaches (South Africa, Department of Higher Education and Training, 2013). In supporting rather than criticizing, educators must focus on what the student know. When knowing the criteria ahead of time the students have a sense of ownership of their own work. Using performance standards and exemplars also decreases the frustration levels of the students (Gregory et al., 1997). The information collected in AfL is used to report to the student by offering descriptive, on time feedback and to provide the educator with information to allow for changes in instruction for individual students or groups of students. Black and Wiliam (2010) posit that feedback is a key component in AfL. Furthermore, Cooper (2007) and Davies (2000a) support this notion by asserting that the quality of the feedback matters, as well as the timing. They also emphasize the fact that written descriptions improve the quality of feedback, because descriptive feedback specify points of improvement. In allowing students to adjust or change what they are doing through descriptive feedback, students are more likely to be successful (Davies, 2000a).

Furthermore, Davies (2000b) highlights the importance of descriptive; pointing out that it takes place during, as well as after the learning. It is easily understandable and related directly to the learning; it is specific so that performance can improve; it involves choice on the part of the student as to what and how to receive feedback; it is part of an ongoing conversation about learning.

Gregory et al. (1997) provide quick ways that a teacher can give immediate feedback to guide the student's learning, without giving a score or grade. One such example, illustrated in Table 2.2 (rubric adapted from Gregory et al., 1997, p. 35), is the MET/NOT YET/I NOTICED criterion-reference.

Table 2.2: Example of a MET/NOT YET/I NOTICED rubric

Criteria for: ***Reader response journal***	**MET**	**NOT YET**	**I NOTICED ...**
1. Recorded a minimum of 3 results for the experiment.	√		*You recorded 5!*
2. Show all calculations and present the results in a graph.		*X*	*You only wrote final answers.* *No calculations and graphs.*
3. Group work (take part in discussions, make claims, counter-claims, etc.)	√		*You chaired the group session well.*

This rubric gives the student immediate feedback when the criteria are set up in a rubric and the educator is simply checking off 'MET' (= met learning objective) or 'NOT YET' (= did not meet learning objective) and giving descriptive feedback in the 'I NOTICED' column. The students use the predetermined set of performance indicators in the criterion-referenced rubric to assess their performance. Other disciplines also use criterion-referenced rubrics for example, when a sport coach is training an athlete or a driving instructor teaching a learner driver. Performance standards and rubrics are becoming more and more common in the educational setting, as teachers see the merit in allowing the students to know what the criteria are before they begin the task (Cooper, 2007). Another technique that is to invite students' contributions in setting the criteria. This increases student buy-in and makes them accountable to the standards they have set themselves.

All the AfL strategies and activities have some element of feedback, which makes explicit connections between students' thinking and the learning that is expected. They address the misinterpretations and lack of understanding that students may have and help identify the next steps and an example of what good work looks like (Davies, 2000b). AfL strategies will support or challenge an idea that a student holds and allow the educator to provide recognition for achievement and growth, and to give precise directions for improvement. Good descriptive feedback should also cause students to think about, and allow them to respond to, the educator or peer's suggestions.

2.8.3 AfL and Bloom's taxonomy. Benjamin Bloom (1956) developed the framework for categorizing educational goals familiarly known as Bloom's Taxonomy. Generations of school and college educators have been using this framework, consisted of six major categories: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. The categories after Knowledge were presented as 'skills and abilities', with the understanding that knowledge was the necessary precondition for putting these skills and abilities into practice. While each category contained sub-categories, all lying along a continuum from simple to complex and concrete to abstract. The taxonomy popularly known for its six main categories, namely:

Knowledge – Involves the recall of specifics and universals, the recall of methods and processes, or the recall of a pattern, structure or setting.

Comprehension – Refers to a type of understanding or apprehension that the individual knows and make use of the material or idea without necessarily relating it to other material or seeing its fullest implications.

Application – Refers to the use of abstractions in particular and concrete situations.

Analysis – Represents the breakdown of a communication into its constituent elements or parts such that the relative hierarchy of ideas made clear and/ or the relations between ideas expressed made explicit.

Synthesis – Involves the putting together of elements and parts to form a whole.

Evaluation – Engenders judgments about the value of material and methods for given purposes.

In 2001, a group of cognitive psychologists, curriculum theorists and instructional researchers and testing and assessment specialists revised Bloom's Taxonomy. They regarded the original taxonomy as static in nature and changed it to have a more dynamic conception in terms of classification. The authors of the revised taxonomy underscore this dynamism, using verbs and gerunds to label their categories and sub-categories (rather than the nouns of the original taxonomy). These ‘action words’ describe the cognitive processes by which thinkers encounter and work with knowledge, for example, Remember, Recognizing, Recalling, Understand, Interpreting, Exemplifying, Classifying, Summarizing, Inferring, Comparing, Explaining, Apply, Executing, Implementing, Analyze, Differentiating, Organizing, Attributing, Evaluate, Checking, Critiquing, Create, Generating, Planning and Producing.

In the revised taxonomy, knowledge is at the basis of six cognitive processes. The authors created a separate taxonomy of the types of knowledge used in cognition, for example factual knowledge, knowledge of terminology, knowledge of specific details and elements, conceptual knowledge, knowledge of classifications and categories, knowledge of principles and generalizations, knowledge of theories, models and structures, procedural knowledge, knowledge of subject-specific skills and algorithms, knowledge of subject-specific techniques and methods, etc. Table 2.3 illustrates a summary of the Revised Bloom’s Taxonomy with the six cognitive processes, lower to higher levels, and four types of knowledge from concrete to abstract. The action words are indicated where the knowledge and cognitive dimensions combine.

Table 2.3: Bloom’s Revised Taxonomy

		Knowledge Dimension			
		FACTUAL	**CONCEPTUAL**	**PROCEDURAL**	**METACOGNITIVE**
Cognitive Dimension	**CREATE**	*Generate*	*Assemble*	*Design*	*Create*
	EVALUATE	*Check*	*Determine*	*Judge*	*Reflect*
	ANALYSE	*Select*	*Differentiate*	*Integrate*	*Deconstruct*
	APPLY	*Respond*	*Provide*	*Carry out*	*Use techniques*
	UNDERSTAND	*Summarize*	*Classify*	*Clarify*	*Predict*
	REMEMBER	*List*	*Recognizes*	*Recall*	*Identify*

In order to get effective feedback, educators must ask appropriate questions verbally or in written tasks. Many educators do not have the skill to ask or formulate probing questions, which appropriately assess the understanding and knowledge of students. Bloom’s Revised Taxonomy is a useful tool to assist educators in this regard. This taxonomy encourages all students to get involved in classroom discussions. It helps educators formulate high-order questions, which facilitate deep learning, and gives students an opportunity to learn the same questioning skill and to share their thinking with at least one other learner, in terms of inter-argumentation. Furthermore, it encourages students to think critically and helps them to challenge different viewpoints during the dialogical argumentation process. Bloom's taxonomy is also a useful technique in the scaffolding process to improve their understanding. Furthermore, it helps to ensure that students really listen to each other by explaining their partner's ideas to the class and to respond to questions from the class.

2.9 Chapter summary

This chapter provided the context for the study as well as a review of literature related to the major theoretical concepts. It presented an overview of South African education reform within the school and post-school sectors, the importance of the socio-cultural background of students and the western science and indigenous knowledge worldviews. The relative dimensions of indigenous knowledge and western science with which students enter the science classroom were also discussed.

The theory of constructivism was unpacked to indicate its relevance in dialogical argumentation instruction as well as formative assessment. Toulmin's (1958) Argumentation Pattern (TAP) and Ogunniyi's (2007a) Contiguity Argumentation Theory (CAT) were interrogated to highlight their importance in the teaching and learning of science. There followed a discussion of the Dialogical Argumentation Instruction Model (DAIM), a pedagogical methodology founded on the TAP, CAT and constructivism, that creates discussion spaces within the classroom aligned to the learning objectives. Furthermore, Assessment for Learning was positioned within the general assessment context and the relevant aspects were emphasized, with special reference to feedback in terms of Bloom's taxonomy. The next chapter presents details of methodology adopted in the process of collecting data for the study.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The aim of this study is to determine the effectiveness or otherwise of the Dialogical Argumentation and Assessment for Learning Instructional Model (DAAFLIM) in enhancing the TVET students' conceptions of selected science topics namely, SI-units, dynamics, statics and energy. More specifically, this chapter presents the research methodology, research design and a narrative of the process adopted in the study. Furthermore, the development of the DAAFLIM, processes of validating the instruments as well as their application in a classroom context are explained. Finally, the discussion on limitations, delimitations and ethical considerations are presented.

3.2 Research paradigm

This study adopts a hermeneutic approach, i.e. the interpretation and understanding of events through analysis of human participants in the events (Regan, 2012), and is an attempt to explore and interpret teaching methodology and formative assessment. It is evident from the literature that when selecting a research paradigm, it is worth considering that boundaries between paradigms are often not as clear-cut as they are assumed to be. Several writers have pointed out that interpretive and constructivist paradigms frequently transmute into each other, and that the boundaries between these can become blurred (Denzin & Lincoln, 1998; Merriam, 1998; McGahie, 1986). According to Terre Blanche, Durrheim and Painter (2006, p. 273), "… the interpretive paradigm involves taking people's subjective experiences seriously as the essence of what is real for them, is making sense of people's experiences."

Constructivism refers to how signs and images have powers to create particular presentations of people and objects. Social constructivist researchers want to show that thoughts and feelings, which people assume as private, are the result of systems of meanings that are socially constructed (Terre Blanche et al., 2006). The key difference between the interpretive and constructivist paradigms is at the ontological level, where different assumptions of how meaning is constructed – providing 'rich descriptions' of how actors construct their social realities and interpreting the social world. In respect of teaching and formative assessment, construction uses both perspectives constructing meaning in both ways. Since the interpretive-constructivist paradigm seems the most appropriate approach, a comparative analytical case study is used.

3.3 Research design

This study used a mixed-method approach collecting data quantitatively and qualitatively for analysis. Yin (2003) asserts that these methodologies complement each other. Mixed-method research is a good design to use as it builds on the strengths of both quantitative and qualitative data (Creswell, 2009, p. 510). Although most of the data was collected through qualitative research methodologies such as interviews and observation schedules, questionnaires and the Science Achievement Test (SAT) were used to obtain quantitative data. The data collected provide descriptive portraits of how the educators and students engaged with teaching, learning and assessment of the curriculum.

Therefore, this research design is based on a case study approach, which enabled the researcher to move 'inside the classrooms' and capture the interactions. Furthermore, this study captured the dialogue, presenting the starting points, voices, opinions and practices of the students and educators.

3.3.1 Quasi-experimental design. A quasi-experimental, pre-test–post-test design informed the process of investigation. The quantitative aspect of the quasi-experimental design measured the differences between the conceptual understanding of selected science topics, i.e. SI-units, Dynamics, Statics and Energy, of both the experimental group and the control group (Punch, 2009). Figure 3.1 shows the quasi-experimental design format used.

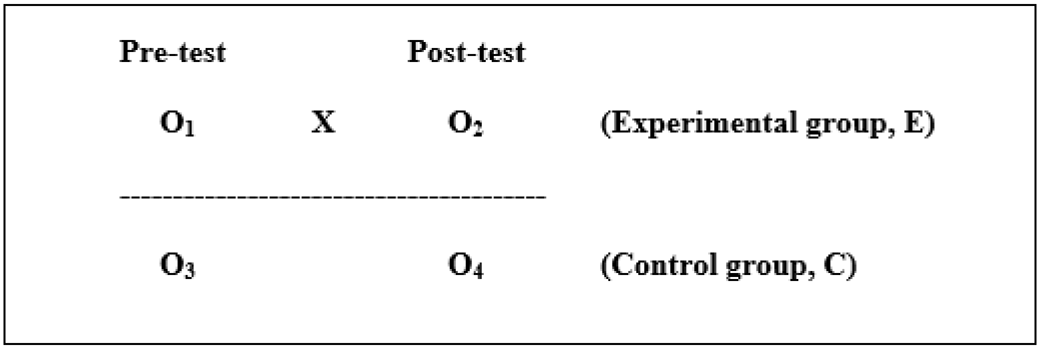

Figure 3.1: Quasi-experimental design

O_1 is the pre-test observation and O_2 the post-test observation of the experimental group (E). X depicts the use of the DAAFLIM intervention used during the instruction of the experimental group (E). The control group (C) pre-test observation (O_3) and the control group post-test observation (O_4) received tuition of the selected topics in an expository traditional way, which is largely lecture and demonstration method. The treatment variables in this research study were the different instructional methodologies, namely the DAAFLIM for the experimental group and the traditional instruction method (TIM) for the control group. Ogunniyi (1992) asserts that the treatment variable is responsible for the outcome a researcher obtains; and the dependent or criterion variable is directly related to the treatment variable. The dependent variable in this study was the performance scores of the students within the different pedagogical settings at the end of the study. In order to ensure that the results of this research were reliable and fair, the E-group and the C-group received content of the activities and course material with similar degree of difficulty, covering the same knowledge content during the intervention period.

3.4 Research sample

Two intact engineering science class groups at a TVET College, with 30 students each, participated in this study. Due to attrition, the number of students in each group reduced to 26. The two class groups were from different campuses of the same TVET College in order to minimize interaction and sharing of information between the participants of the different groups, to avoid possible contamination of data. These class groups were purposefully selected out of four groups at each campus who wrote the pre-test of the Science Achievement test (SAT). Table 3.1 depicts the pre-test results of the four groups.

Table 3.1: Pre-test mean percentage of groups at the two campuses

Campus	Group A %(N)	Group B %(N)	Group C %(N)	Group D %(N)
Mechanical engineering campus	13% (25)	24% (30)	33% (29)	5% (32)
Electrical engineering campus	19% (33)	17% (25)	27% (30)	10% (30)

The results indicate that the performance scores of mechanical engineering group B and electrical engineering group C were most similar and were therefore selected as the research groups. The researcher selected the electrical engineering students as the experimental group, because he was located at the campus. It was convenient for the researcher to induct the experimental group in the protocol and logistics of the DAAFLIM, with specific reference to the Toulmin's Argumentation Pattern (TAP), two weeks before the commencement of the study. Students were workshopped in the elements of TAP - how to construct appropriate claims, warrants, qualifiers and rebuttals. Table 3.2 depicts a breakdown of the research groups in terms of gender, age and cultural group.

Table 3.2: Sample distribution in terms of gender, age and cultural group

Groups	Gender		Age (years)		Cultural group		
	Male	Female	18-20	>20	Coloured	Black	White
Control group (N=26)	12	14	17	9	4	20	2
Experimental group (N=26)	15	11	15	11	10	15	1
Total	**27**	**25**	**32**	**20**	**14**	**35**	**3**

3.5 Research setting

The campuses of the research groups are situated in different middle-income neighbourhoods in suburbs of the Western Cape, South Africa. The overall academic performance of students at these two campuses are similar in general, about 55% average pass rate over all engineering science courses. Although the two campuses specialize in different engineering science disciplines, mechanical and electrical, the ethos and culture of teaching and learning at the campuses are the same. In both instances, the medium of instruction is English, the majority of educators make use of lecture-style teaching, the structure of the courses is the same and the students are mainly from historically disadvantaged communities. The campuses also have a strong work-integrated learning (WIL) approach aligning academic and workplace practices for the benefit of the student.

3.6 Intervention: Dialogical Argumentation Assessment for Learning Model (DAAFLIM)

Figure 3.2 illustrates the DAAFLIM with different formative assessment strategies used in this study.

3.6.1 The development of DAAFLIM. A group of PhD students, under the guidance of their supervisor and inspired by the formative assessment research of Black and Wiliam (2010) and Cooper (2007) adapted the DAIM into the DAAFLIM, by merging formative assessment strategies into each learning space of the DAIM framework. DAAFLIM enables educators to track the progress and to be responsive to students' contingencies at any given point of instruction. DAAFLIM reduced the learning spaces of the DIAM framework from six to four to make it more practical for the TVET college context - less time is spent per lesson than at schools where the DAIM is proven effective. Although formative assessment is part of most educators' instruction, its crucial and integral role in the teaching and learning process is not exploited adequately. The DAAFLIM, however, makes formative assessment and feedback explicit and, therefore, ensures that the objective of the learning activity is met during each DAAFLIM
process.

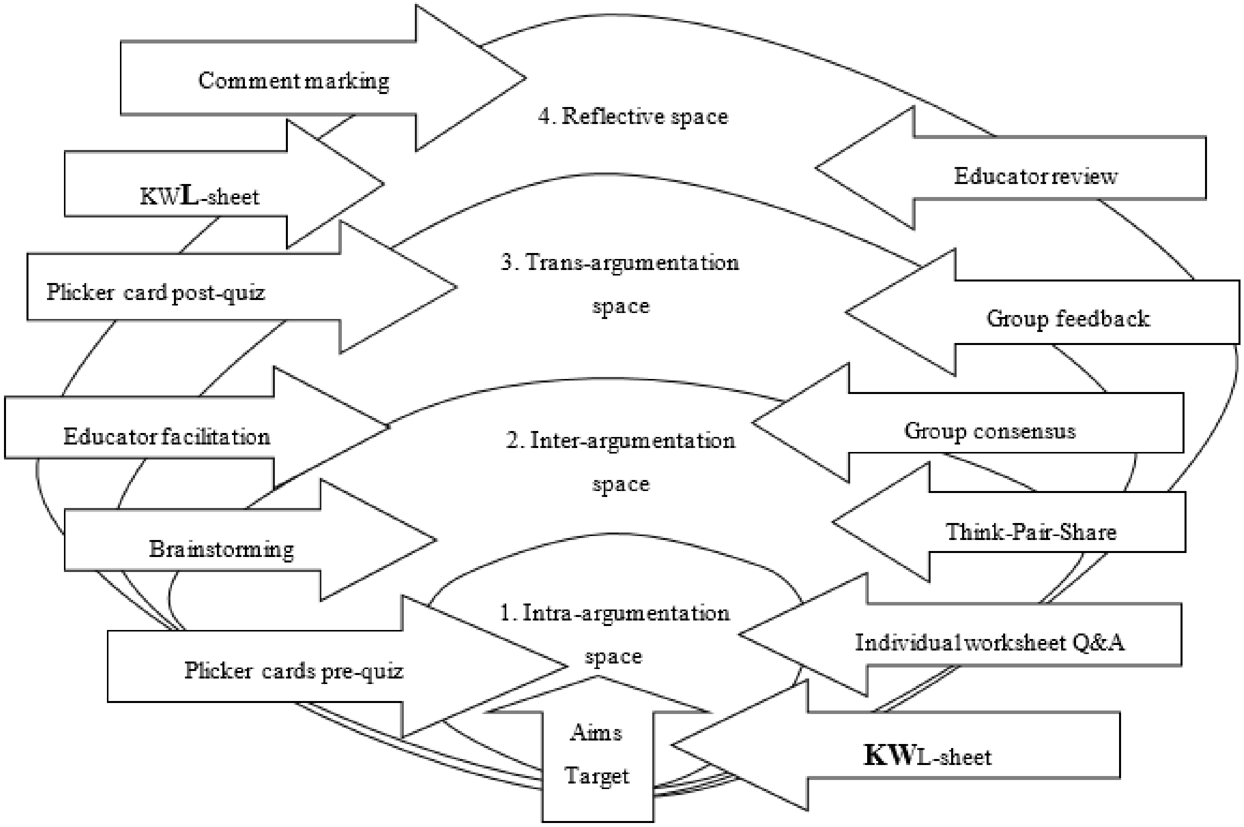

Figure 3.2: The DAAFLIM model

Figure 3.2 illustrates the different DAAFLIM strategies used during the instruction process to determine the student's progress and to adapt the teaching process to remediate problem areas or misconceptions. The various strategies employed during this study at the different stages of the DAAFLIM were as follow:

Learning space 1 – Intra-argumentation space (Individual):

KWL-sheet: At the beginning of the lesson, students created a grid with three columns with headings: (1) what they **K**now (prior knowledge), (2) what they **W**ant to know (expectations) and (3) what they have **L**earnt (reflection). They begin by brainstorming, and fill in the first two columns and then complete to the third column at the end of the activity (Appendix 15).

Making aims clear: The educator wrote lesson objectives on the board at the beginning of the lesson and talked to students about why they are studying the specific topic. Thereafter, the educator contextualized the short-term and long-term aims.

Target setting: Students set their targets at the beginning of the lesson.

Plicker cards (pre-quiz): The educator quickly checked which concepts students understand e.g. by referring to the quiz results (correct answers) and which concepts they are struggling with (wrong answers). The quiz results informed the direction of the lesson activities.

Individual worksheet: Students answered the questions on the worksheet individually, without interacting with anyone in order to articulate their understanding of the topics.

Self-assessment: Students evaluated their own responses and thought about their own learning. They had to make sense of the questions and answers, relating it to previous learning.

Learning space 2- Inter-argumentation space (Peer & group):

Think-Pair-Share: Within the groups, students paired and gave feedback to each other about his/ her individual responses to the questions of the worksheet; and they discussed the answers.

Brainstorming: Group members contributed and interrogated the topics of discussion until the group reached consensus.

Educator facilitator: The educator walked around the classroom, assisting and intervening in discussions, providing guidance. The educator also engaged some groups in focused discussion.

Group consensus: Students reflected and compared their responses to the responses of the rest of the group in order to reach consensus as a group.

Learning space 3 – Trans-argumentation space (Inter-group/ whole class):

Group feedback: Groups gave feedback to the rest of the class about their discussions, which made the educator aware of learning needs in a manageable way. Group feedback also drew more attention to, and presented information that has already been ordered and sorted, requiring less repetition by the educator.

Plicker cards (post-quiz): The educator quickly checked which concepts students understood the concepts by referring to the post-quiz results (correct answers), and which concepts they did not master (wrong answers). The educator and the students used the results to gauge the conception that took place during the lesson. The post-quiz result also indicated topics requiring more attention.

Learning space 4 – Reflective space (Review):

Educator review: The educator reviewed the lesson using the results of the Plicker cards pre- and post-quiz, group feedback, KWL-sheets and verbal questioning to elicit further understanding from students. The educator asks students to suggest ways to alter the lessons to improve their understanding. The educator modelled the review by evaluating the lesson in relation to the feedback of the students.

KWL-sheet: The students completed the third column (**L**earnt) of the KWL-sheet, reflecting on what they have learnt during the lesson.

Focus group(s): After the lesson, the educator identified at least one group for a focused discussion. During the focus group discussion, the dialogue between the educator and groups of students reflected on a particular topic of the lesson, giving the educator a deeper sense of the students' conception. The educator concentrated on the quality of the dialogical.

Comment marking: After the lesson the educator marked the students' worksheet and gave constructive comments, instead of a grade (score). At the beginning of the next lesson, students receive their marked worksheets to reflect on the feedback.

A very useful tool for the DAAFLIM educator is the lesson plan template illustrated in Table 3.3, providing guidance in terms of the learning spaces. When the educator completed the lesson plan template, he made use of the "Backward design" and the unifying framework for formative assessment to close the learning gap during instruction.

Table 3.3: The DAAFLIM lesson plan template

Space	DAAFLIM activities		Time
1. Individual	**Making aims clear:** Clarifying, sharing and understanding learning intentions. **Assessing prior knowledge:** What you already **K**now and what you **W**ant to know (**KW**L). **Enquiry questions:** Activity worksheet. **Self-evaluation**: Activating students as owners of their own learning.	● Teacher introduces the topic and explains the outcomes. ● Handing out worksheets and material. ● Students complete "what they already **k**now" (**K**) and "what they **W**ant to know" (**W**) on the **KWL** sheet. ● Students complete the activity or worksheet individually.	20 to 27 minutes (±35%)
2. Group	**Peer assessment:** Activating students as instructional resources in groups. **Discuss scientific words:** Discussions - key concepts **Student review:** Mini-plenary, review each student's responses in the groups. **Teacher review (facilitation):** Scout groups to guide/ assist.	● Groups appoint coordinator and scribe. ● Pairs of students share responses of worksheet exercises. ● Debate in larger group ● Reach group consensus. ● The scribe writes down the group consensus with the different TAP elements. ● Group choose presenter(s)	7 to 9 minutes (±25%)
3. Inter-group/ Whole Class	**Discuss scientific words:** Discussion takes key words and looks at them specifically. **Group feedback (plenary):** Engineering effective classroom discussions, activities and learning tasks that elicit evidence of learning. **Teacher review:** Working with students to provide them with information to understand problems and solutions.	● Presenters of each group give feedback to the class. ● Class discussion takes place in terms of the TAP protocol. ● Educator facilitates and summarizes the discussions. ● Educator links discussions with the lesson outcomes.	11 to 15 minutes (±25%)
4. Reflection	**Self-evaluation:** Activating students as owners of their own learning by self-regulation. **Assessing post-knowledge:** What you have **L**earnt (**KWL**) **Feedback:** Comments in notebook, learning diary or journal.	● Students complete "what have I **l**earnt" (L) on the **KWL** sheet. ● Teacher collects the **KWL sheet** and completed activity worksheets.	7 to 9 minutes (±15%)

3.6.2 DAAFLIM strategies. Although there are many formative strategies, the following strategies were most effective during the lessons. The educator decides on the DAAFLIM-strategies based on the learning objective and use it in the same sequence as in Figure 3.2 or differently (see Appendix 17 for more strategies). These strategies relate to each other and overlap in many instances. I used the following strategies during the instruction process:

a) Comment marking. I marked the students' worksheets and gave constructive comments instead of a grade or score. In some instances, I selected one piece of work per week giving detailed written feedback to each student. I also gave the reference criteria used for written feedback at the start of the lesson. The comment included specific feedback about aspects of the work that the students have done well and specific suggestions to improve their work. In many instances, students received feedback orally. At the start of the each new lesson, students receives their worksheets with the marking comments to improve their responses.

b) Plicker-quiz cards. I used Plicker-quiz cards to collect real-time data indicating concepts students understand, and which require more attention. This information informed me to proceed or spend more time on a topic. I conducted the pre-quiz before the individual learning space, and the post-quiz at the end of the inter-group/ whole class learning space to review each student's answers. The quiz results helped me to identify who needed remedial assistance or enrichment exercises. I used a computer with internet connection and a smartphone to scan each student's unique coded Plicker card (Figure 3.3).

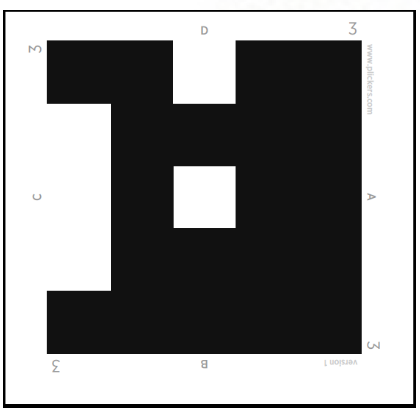

Figure 3.3: A sample of a coded Plicker card

The quizzes for a particular lesson consisted of questions based on the topic varying from easy to very challenging (Appendix 15).

c) Peer/ group feedback. Students gave each other feedback during the Think-Pair-Share, group discussion and whole class discussion. They assessed each other's responses and provided comments relating to a specific success criterion.

d) Educator facilitator. I walked around the classroom monitoring the discussions in the pairs and groups. In order to ensure the discussion stay focused on the topics, I interjected, gave guidance in the group discussions. At the end of the lessons, I selected groups and conducted focused discussion of specific topics. I also encouraged the students by praising their participation and performance.

e) Question-and-answer. I used this strategy in all the learning spaces with varying degrees. Students also used it extensively during group and whole class discussion. It is important to note that it requires a special skill, eliciting thought provoking responses, stimulating deep learning, posing probing questions, allow enough waiting-time (3 seconds) to response and playing 'devil's advocate'. I used these techniques to gauge the students' conceptions. During the discussions, I used the incorrect responses from the students as opportunities for learning in the subsequent instruction.

3.7 The preliminary studies

Ogunniyi (1984b) asserts that the items of instruments tend to evince ambiguous responses unless they are well written, they. The construction of rating scales is not just a matter of writing a list of statements; it requires several revisions and pilot testing to determine which items are suitable. Therefore, the preliminary study of this project determined the feasibility of the study, the practicality of the DAAFLIM framework, and tested the validity and reliability of the instruments. It also explored the other aspects of this study, namely students' worldviews, the use of DAAFLIM in the conception of concepts of Dynamics, Statics and Energy, and the biographical background of students. Furthermore, the preliminary study determined how much time is required to induct students adequately in the protocol of the DAAFLIM.

Postgraduate science students at the University of the Western Cape validated and rated the instruments of the pilot study. The main study used the valuable feedback to improve and strengthen the instruments with regard to structural and content reliability. The findings of the pilot study revealed certain shortcomings with regard to the implementation of DAAFLIM namely, time constraints, structural strength of the questionnaires and the appropriateness of the dialogical argumentation protocol. I presented the major findings of the preliminary study at an international educators' conference for review of comments from experts in this field (George, 2012). The main study rectified the shortcomings of the preliminary study.

3.8 Validity and reliability of the instruments

Making valid inferences from data and having consistent data are as important in qualitative research as they are in quantitative research study. Merriam (1998) asserts that the following measures ensure validity and reliability: "Triangulation, member checks, long-term observations, peer examination, participatory or collaborative modes of research and researchers' bias". Merriam defines triangulation as:

> A process of using more than one source to confirm information data from different sources, confirming observations from different observers and confirming information with different data collection methods. With the discovery of disconfirming information, seeking reasons for contradiction frequently points to the direction for extending or modifying explanations, instead of discarding them. (Merriam, 1998, p. 276)

Triangulation is a process for increasing the validity of a given study (Denzin, 1978). I triangulated the data gathered from the lesson observation schedules, questionnaires, Science Achievement Test (SAT) scores and focus group interview responses to strengthen the validity of the instruments. There should be a good balance between the internal and external validity of an instrument. Internal validity deals with accuracy and the control of most extraneous variables of the instruments and external validity refers to the usefulness of the instrument. Reliability means that an instrument should consistently reflect the construct that it is measuring. In order to determine the association between the performances of two tests, researches make use of a correlation coefficient (Ogunniyi, 1992). The correlation coefficient, r, ranges between -1.00 and +1.00. A correlation coefficient closed to +1.00 is said to be a positive correlation, while one close to -1.00 is said to be negative correlated. If the correlation coefficient is close to or at zero, then it shows no correlation and therefore there will be no reliability. A reliable instrument gives comparable scores when administered to the same group of participants at different intervals of time. A person should get the same score in a questionnaire that she completes at different times.

The reliability of the Science Achievement Test obtained a value of r = .73 using the Cronbach's alpha reliability test (SPSS), suggesting a strong positive reliability.

Formula used to calculate the Cronbach Alpha coefficient:

$$\propto = \left[\frac{N}{N-1}\right]\left[\frac{S_x^2 - \sum S_i^2}{S_x^2}\right]$$

Where: N = Number of items in the measuring instrument

S_i^2 = Variance of an item in the measuring instrument

$\sum S_x^2$= Sum of variance of each item in the measuring instrument

The content and construct validity of all the instruments, NOSIKS-Questionnaire, activity sheets and interview schedules were evaluated and ranked by a group of postgraduate science students at the School of Science and Mathematics Education at the University of the Western Cape. The assumption is that experts are not biased, but possess relatively equal abilities and judgement. The SAT was refined based on the preliminary study to address the research questions effectively.

3.9 Instruments

In order to make it easy tracking down the participants for further engagement if the initial responses were unclear, I assigned codes to all the instruments and responses of students. Figure 3.4 provides a summary of the instruments and analytic tools used in this study in relation to the research questions.

Table 3.4: Summary of instruments and analytic tools

Instrument	Analytic tool	DAAFLIM strategy	Qualitative/ Quantitative	Research question
1. NOSIKS-Q	CAT	Individual Q&A, Feedback	Quantitative & Qualitative	RQ1 & RQ2
2. SAT	CAT & TAP	Individual Q&A, Feedback	Quantitative & Qualitative	RQ3 & RQ4
3. Worksheets	CAT, TAP & ZPD	Individual, Q&A, Braining, Group consensus	Qualitative	RQ3 & RQ5
4. Lesson observation schedule	FIAC & Communication framework	KWL worksheet, Think-Pair-Share, Plicker card quiz, Peer- & Group-feedback, Educator review	Quantitative & Qualitative	RQ3 & RQ5
5. Focus group interview schedule	CAT & TAP	Group feedback	Qualitative	RQ3

3.9.1 Nature of Science and Indigenous Knowledge Systems-Questionnaire (NOSIKS-Q). References to the history of science are particularly useful for helping students understand the nature of science (NOS). Proponents of NOS have often advocated using the history of science in science teaching to promote student understanding of one or more the core NOS tenets (Howe, 2007). Though the development of NOS core tenets has been an important step in establishing targeted benchmarks for NOS instruction, educators need examples that they can use instrumentally in the classroom to give students meaningful contexts from which they can interpret the relevance of NOS and IK issues.

Onwu and Ogunniyi (2006) developed the Nature of Science and Indigenous Knowledge Systems-Questionnaire (NOSIKS-Q) deriving it from the Traditional Cosmology Test (TCT) and Characteristic of Science (COS) questionnaire (Ogunniyi et al., 1995). A research team of science education lecturers affiliated to different universities in South Africa contributed to the development of the original NOSIKS-Q; they were at the forefront of indigenous knowledge research in South Africa. I choose the NOSIKS-Q to assess students' knowledge, understanding and views of the nature of science and indigenous knowledge, as well as the educators' view on the integration of science and IKS in the science classroom.

The NOSIKS-Q in this study was adapted to establish the degree of conception the students held about the nature of science and nature of indigenous knowledge systems, which was included in Section C of the SAT. The questionnaire also gathers biographical data about the students' age, gender and socio-economic backgrounds. The students' responses to the questionnaire revealed their conceptions of natural phenomena and science tenets in terms of lived experience and socio-cultural background. The NOSIK-Questionnaire consists of two sections: Natural phenomena items and nature of science (NOS) tenets. The natural phenomena items were evolution, hysteria, the rainbow and lighting. The NOS tenets were empirical, societal, universal and subjectivity.

It was very challenging to categorize the responses of the students in the NOSIKS-Questionnaire into Western Science and Traditional Knowledge conceptions that were at variance with the assessment guide, because some students interpreted the real-life contexts differently in the questions of the Science Achievement Test. In ascertaining the acceptability of the responses of the students, I had to be cautious not to reduce or misinterpret the students' views. I became aware of the misconceptions and belief systems among students when teaching them.

3.9.2 Activity worksheets. I used the findings, recommendations and reviews of the preliminary study to design the worksheets, in order to stimulate critical thinking, interaction, and lively debates (Slavin, 1983). The worksheets included the two most important aspects; detailed steps (instructions) and a criterion-referenced rubric making it easy to assess and evaluate individual learning gained from individual and group tasks (Van Rooyen & De Beer, 2007, p. 75). The students completed the activity worksheets during the intervention process and was analysed to assist and explain the enhancement, or not, of conception by students.

The worksheets based on the DAAFLIM approach including each of the following concepts: SI-units, Dynamics, Statics and Energy (Appendices 10 – 12). The students completed the worksheets individually, during the intra-argumentation stage, thereafter, shared in the group work discussions, the inter-argumentation stage, where the group reached consensus about the answers to the worksheet. The intervention took place over a period of eight weeks (Appendix 8).

3.9.3 Lesson observation schedule. The researcher developed the classroom observation schedule after being peer reviewed and rated by postgraduate students and science educators, modified to include the recommendations of the preliminary study. The schedule allows for the recording of classroom interactions and observer's comments. The lessons were audiotape-recorded and later transcribed.

Using lesson observation schedules the researcher calculated teacher-talk and learner-talk ratios, indicating learner-centeredness to compare the interaction in the experimental and control classrooms. Wray and Kumpulainen (2010) assert that a high frequency of student interaction influences the achievement and performance of students positively. The best-known way to analyze classroom interaction is probably the Flanders Interaction Analysis Categories (Flanders, 1970). This classroom observations, provided evidence of the differences in teaching patterns that distinguish DAAFLIM from TIM and explain differences in learning outcomes associated with the different styles of teaching (Wragg, 1999). The Flanders Interaction Analysis Categories (FIAC) consist of ten categories of communication; seven when the teacher is talking (teacher-talk), two when a learner is talking (learner-talk) and one when there is silence or confusion. An observer makes timed observations every ten minutes, categorizing the behaviour in class into one of the ten categories. Table 3.5 illustrates the ten categories.

Table 3.5: Flanders' Interaction Analysis Categories (FIAC)

	Tally
Teacher-talk: ▪ Accepts feelings: accepting and clarifying learners' feelings ▪ Praises and encourages learners' actions or behaviour. ▪ Accepts or uses ideas and suggestions of learners. ▪ Gives facts or opinions about content or procedures. ▪ Asks questions about content, expecting learners to respond. ▪ Gives directions, commands or orders. ▪ Criticises or justifies authority.	
Learner-talk: ▪ Responses: talk by learners in response to teacher. ▪ Initiation: talk by learners, which they initiate.	
Silence: ▪ Silence or confusion: pauses or short periods of silences.	

The communicative approaches model determines the teacher-learner-talk ratio to analyze the dialogical discourse in the classroom (Mortimer & Scott, 2003). Figure 3.4 illustrates the model, consisting of four categories generated from the combination of two dimensions: interactive – non-interactive and authoritative – dialogic.

	Interactive	Non-interactive
Authoritative Focus on science's view	Questions and Answers I-R-F Teacher-learner-talk ≈ 1:1 (Teacher talk: 45-55%)	Lecture Teacher-learner-talk ≈ 1,5:1 (Teacher talk: > 55%)
Dialogic Different points of view are considered	Probing, Elaborating, Supporting I-R-F-R-F Teacher-learner-talk ≈1:1,5 (Teacher talk: < 45%)	Review Teacher-learner-talk ≈ 1:1 (Teacher talk: 45-55%)

Note: I = initiation, R = response, F = feedback

Figure 3.4: Communicative framework of classroom talk

The communicative framework used to determine the learner-centeredness of the activities in the experimental and control groups assisted the observation process.

3.9.4 Criterion-referenced criteria. Gregory et al. (1997) argue that effective success criteria drawn up before engaging in a learning activity should include learning outcomes and what students value for a task. The criteria were not only set for questions, but for complete activities and lessons. Table 3.6 illustrates a rubric template used in the worksheets.

Table 3.6: MET/NOT YET/I NOTICED rubric template

Criteria for: …………………………………...*(topic)*	**MET**	**NOT YET**	**I NOTICED ...**
Outcome 1: ……………………………………			
Outcome 2: …………………………………..			
Outcome 3: ……………………………………			

3.9.5 Science Achievement Test (SAT). Both the E-group and C-group students wrote the SAT before the commencement of the study and at the end of the study. I used the data collected from the SAT to determine whether there was a significant difference between students who were exposed to the DAAFLIM instructional model and those not exposed, in understanding the selected topics. The questions developed based on the revised Bloom's taxonomy clarified the objectives of the questions in the SAT. Bloom (1956, p. 186) asserts that having an organized set of objectives helps teachers to “plan and deliver appropriate instruction, design valid assessment tasks and strategies and ensure that instruction and assessment are aligned with the objectives". The taxonomy shows a progression from the simplest to the most complex levels of knowledge and intellectual skills.

Furthermore, Ogunniyi (1992) asserts that social sciences instruments initially developed by psychologists to study underlying conditions affecting a person’s behaviour. These tests include the categories of achievement tests, criterion-referenced tests, intelligence tests, aptitude tests and personality tests. Therefore, this study used an achievement test “which measures what a person knows or has achieved after a learning experience” (Ogunniyi, 1992, p. 70). Table 3.7 indicates the levels of Bloom’s taxonomy distributed across the different questions of the SAT and the corresponding mark allocations (Appendix 9).

Table 3.7: Distribution of Bloom’s taxonomy in the SAT

Instrument	**Analytic tool**	**DAAFLIM strategy**	**Qualitative/ Quantitative**	**Research question**
1. NOSIKS-Q	CAT	Individual Q&A, Feedback	Quantitative & Qualitative	RQ1 & RQ3
2. SAT	CAT & TAP	Individual Q&A, Feedback	Quantitative & Qualitative	RQ1, RQ2 & RQ3
3. Worksheets	CAT, TAP & ZPD	Individual, Q&A, Braining, Group consensus	Qualitative	RQ1 & RQ2
4. Lesson observation schedule	FIAC & Communication framework	KWL worksheet, Think-Pair-Share, Plicker card quiz, Peer- & Group-feedback, Educator review	Quantitative & Qualitative	RQ1 & RQ2
5. Focussed group interview schedule	CAT & TAP	Group feedback	Qualitative	RQ2

The SAT consists of the following concepts: SI-units, Dynamics, Statics and Energy, taught during the intervention period. Table 3.8 illustrates the content and mark allocation of the SAT.

Table 3.8: Content and mark allocation of the SAT

Concepts	Content	Total Marks (%)
Question1: Units & conversions	Providing names and converting to SI-units of quantities	5 (16%)
Question2: Dynamics	Draw and interpret a graph of motion Applying equations of motion Vector and scalars	10 (32%)
Question 3: Statics	Applying law of moments Newton's third law Components of a force	9 (29%)
Question 4: Energy	Potential energy, kinetic energy, velocity and momentum of a following body	7 (23%)

3.9.6 Focused Group Interviews. In both the experimental and control group focused discussions were conducted with groups of students to gather qualitative data. This assisted me in giving a 'thick' description of the background of the students, reporting their 'voices'. The focused group interviews took place during some of the lesson activities or after a lesson's end, and was audio recorded. I recorded the responses of students in terms of their understanding of concepts and lesson outcomes to identify misconceptions and the confidence with which students presented their arguments (Appendix 14).

3.10 Data analysis

In this study, a number of instrument tools used to collect data namely NOSIK-Questionnaire, science achievement test, worksheets, focus group interviews and lesson observations. The analysis of the data of these instruments produced themes and points of convergence and divergence. Quantitative data derived from the instruments were analysed using Statistical Package for Social Sciences (SPSS) version 20.

The Contiguity Argumentation Theory (CAT), Toulmin’s Argumentation Pattern (TAP) and zone of proximal development (ZPD) analytical frameworks were used as analytic lenses to determine the inductive-deductive reasoning and mental shifts between the pre-test observation and the post-test observation. The data of both the E-group and C-group used to answer the research questions provide a measure or quantify the conceptual change experienced by students in the SAT. The responses in the Science Achievement Test (SAT), transcripts generated from the observation schedules and worksheets were compared for patterns in the data. The assessment of the normality of the data samples dictated whether to use non-parametric or parametric statistical procedures to perform t-test analysis for independent groups and instrument items.

The CAT views learning as a dynamic process, changing an individual’s mental state, conception or worldview from one context to another. There are five categories of conceptions existing in a dynamic state of flux within the mind of an individual. The five categories (see full explanation in section 2.5.2) are the dominant, suppressed, assimilated, emergent and equipollent cognitive states. However, for this study only four of the five categories were used, namely the dominant, assimilated, suppressed and equipollent cognitive states. The emergent cognitive category was not referred to in this study because it was assumed that most, if not all, concepts were new knowledge to them. The cognitive categories of CAT were adapted and expressed in terms of the Traditional Knowledge and Western Science thought systems as follows, to analyze the data:

- Dominant Western Science conception: *The student has a thought system that aligns with the Western-Eurocentric concepts presented in the science classroom*.
- Dominant Traditional Knowledge conception: *The student’s thought system that is aligned with the indigenous worldview based on traditional beliefs, cultural values and personal experiences regardless of his/her awareness of the scientific concepts presented in the classroom.*
- Assimilated conception: *The student abandons his initially Traditional Knowledge conception and adopts the new Western Science conception taught in the classroom, or vice versa.*

- Equipollent conception: *The student holds on to both Traditional Knowledge and Western Science presuppositions and expresses the appropriate conception confidently depending on the context.*
- Suppressed conception: *The student imitates Western Science conceptions while pressing down his/ her own Traditional Knowledge in order obtain high grades in summative assessments, or vice versa.*

I used Toulmin's Argumentation Pattern (TAP) to analyze the justificatory function of argumentation, as opposed to the inferential function of theoretical arguments. The TAP protocol demands that for a good argument to succeed, it needs to provide good justification for a claim. Therefore, it proposed a layout containing six interrelated components for analyzing arguments namely claims, data, warrants, qualifiers, backings, rebuttals and counter-claims (full explanation in section 2.5.1). These are deductive-inductive discourses.

I also used the zone of proximal development (ZPD) to analyze students' thinking and problem-solving abilities considering the following three categories; Category 1: Students who can perform tasks independently, Category 2: Students who can perform tasks with assistance and Category 3: Students who cannot perform tasks even with assistance. The E-group students used DAAFLIM strategies to traverse from the first to the third category, serving a facilitation role during lesson activities, classroom discussions and exercises. The scaffolding approach of DAAFLIM assisted the students in their conception of the concepts (full explanation in section 2.5).

The first and the second research questions determined which worldview students hold on the statements presented in the Science Achievement Test (SAT). Literature suggests that cultural beliefs and values (indigenous knowledge) could affect students' worldviews and initial introduction to Western and Euro-centric science (Allen & Crawley, 1998; Dzama & Osborne, 1999; Waldrip & Taylor, 1999). These worldview conflicts could result from one's "view of man and Nature" and "way of thinking" (Ogawa, 1986). Understanding how students' social and cultural values influence their ways of viewing science may provide educators with valuable information about how to design lessons suitable to the needs of the students. Therefore, the first two research questions determine how the students interact with the NOSIKS-Questionnaire.

Research question three established the comparability of the experimental and control group before the intervention. I analysed the pre-test and post-test responses of the Science Achievement Test (SAT) to determine whether or not conceptual changes took place in the experimental and control group. The effectiveness or otherwise of the DAAFLIM intervention strategy was determined by analyzing the post-test scores of the SAT. Research question three provided perspective and contextualized the background of the students, analyzing the biographical data (gender, age and race) compared to the achievement scores of the SAT.

3.11 Ethical considerations

All the participants of this study gave their informed consent after they received a full explanation of purpose of the study. They were also guaranteed confidentiality, anonymity and non-disclosure of all information gathered. The researcher conducted a workshop with the C-group students exposing them to the DAAFLIM framework. The University of the Western Cape and Northlink TVET College granted ethical clearance and their requirements were strictly adhered to according to their respective ethics practices.

The participants completed letters whereby their permission is requested to use the data collected in the research for the purpose of report writing. Confidentiality and anonymity is guaranteed and they had the option of withdrawing at any given. All questionnaires and interviews are treated in confidence with the guarantee that the results would not be shared with any other participant or used indiscriminately. The following generic checklist is used to track all permission requirements:

1. TVET College council permission letter.

3. Campus managers' and lecturers' permission to use the classes.

4. An oral explanation of the purpose of the study followed to all role players.

5. All interviews are strictly confidential and a confidentiality letter was written to the campuses concerned.

6. Student questionnaires would be anonymous.

7. Names of campuses are kept anonymous and no information about the campus or students or lecturer will be divulged to any person.

8. At the end of the study the TVET College council and the participating lecturers would receive a summary report of the findings of the study conducted.

All the participants signed confidentiality letters prior to individual and focus group interviews., and permission to record the interviews is requested before their participation.

3.12 Chapter summary

This chapter described the research design, sample selection, instrumentation, methodology applied in conducting the study and the process of data analysis. The findings of the preliminary studies and review processes used to inform the methodology of the main study were spelt out. This chapter also discussed the development and implementation of the DAAFLIM framework with specific reference to the formative assessment strategies and learning spaces. A thorough explanation of the instrumentation process and the Science Achievement Test were given, which would determine the effect of the intervention. Delimitations, limitations and the ethical considerations of this study concluded this chapter.

The following chapter discusses the results and findings of the study and chapter five provides a brief summary and implications of the research questions, and recommendations and the conclusions of the study.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The main objective of this study was to determine to what extent Dialogical Argumentation and Assessment for Learning Instruction Method (DAAFLIM) and Traditional Instructional Method (TIM) enhanced TVET experimental-group (E-group) students' and control-group (C-group) students' conceptions of: (1) selected natural phenomena; (2) the Nature of Science (NOS); and (3) selected science topics: SI-units, dynamics, statics and energy. However, to achieve this goal it was necessary to determine their conceptions of these phenomena before exposing them to DAAFLIM and TIM respectively. Thereafter, their responses of the Science Achievement Test (SAT) were analysed to determine if there was a significant difference in the performance scores between the groups with regard to their conceptions of the selected science concepts. I was also interested in finding out if the students' conceptions relate to their sociocultural variables such as gender, age and cultural groups.

4.2 Research Question 1: Students' conceptions of natural phenomena and NOS

What conceptions of selected topics such as; natural phenomena and nature of science (NOS) did E-group and C-group students hold before and after being exposed to DAAFLIM and TIM respectively?

This question seeks to determine: (1) TVET E-group and C-group students' pre- and post-scientific and indigenous conceptions of certain natural phenomena; evolution, hysteria, rainbow and lightning because of their exposure to DAAFLIM and TIM; (2) if any cognitive shifts had occurred in their pre-post-test conceptions because of their experiences with the two instructional strategies. In this regard, the students had to respond and provide their personal, scientific, and indigenous understanding of the sub-themes that follow.

4.2.1 What conceptions of selected natural phenomena did E-group and C-group students hold before and after experiencing DAAFLIM and TIM respectively?

This theme determines what conceptions, Western Science or Traditional Knowledge, students probably hold in the pre-test and the post-test and the possible cognitive shifts, if any, in their response to questions 1 - 4 in the NOIKS-Questionnaire.

Theme 1:

Question 1 - Many scientists believe that the universe occurred by chance (Big Bang), and since then has been undergoing continuous evolution. On the other hand, many people adhere to the religious or cultural view that a Supernatural Being created and controls the workings of the universe. What is your personal and scientific understanding of this phenomenon?

Question 2 – A girl suffering from severe hysteria (excessive or uncontrollable fear and anxiety) could not be cured by a medical doctor, but was cured within a week by a traditional healer. What is your personal and scientific understanding of this phenomenon?

Question 3 – Scientists describe the occurrence of the rainbow as the refractive dispersion ("bending") of sunlight shining through droplets. However, in many traditional cultures, the rainbow is believed to purport a good or evil event in the future. What is your personal and scientific understanding of this phenomenon?

Question 4 - Lightning is an electric discharge in the atmosphere. The very large and sudden flow of the charge that occurs in lightning has enough energy to kill people or do serious damage to buildings. In many traditional beliefs, witches can control lightning. What is your personal and scientific understanding of this phenomenon? (See Appendix 9 for more details).

The Traditional Knowledge (TK) thought system refers to the traditional beliefs, cultural values and personal experiences of students and Western Science (WS) thought system refers to formal science based on the Nature of Science tenets (NOS). The highlighted (bold) terms in the students' responses reflect their conception of the selected phenomena. Using the contiguity argumentation theory (CAT) as a unit of analysis, Tables 4.1.1 – 4.1.4 illustrate the frequency of emerging cognitive states based on the students' responses to the natural phenomena theme.

Table 4.1.1: Frequency of students' responses to evolution phenomenon in terms of CAT categories

CAT category	Experimental group		Control group	
	Western Science	Traditional Knowledge	Western Science	Traditional Knowledge
	(Pre) Post	(Pre) Post	(Pre) Post	(Pre) Post
Dominant: expresses a dominant worldview	(8) 11	(10) 15	(4) 8	(5) 15
Suppressed: imitates a worldview at the expense of own worldview	(0) 3	(0) 1	(0) 2	(0) 2
Assimilated: abandons own worldview & adapts new worldview	(0) 7	(0) 5	(0) 3	(0) 1
Equipollent: holds both worldviews & expresses what is deemed appropriate for a given context	(2) 3	(2) 5	(1) 3	(2) 5
Total	**(10) 24**	**(12) 26**	**(5) 16**	**(7) 23**

Note: $N_{experimental}$ = 26; $N_{control}$ = 26; (pre-test f) post-test f

a) Evolution item. Table 4.1.1 reflects the students' responses to Question 1, based on their personal and scientific understanding of the creation of the universe. The E-group and the C-group students appear to have an overall dominant Traditional Knowledge (TK) conception. A typical dominant TK response from the students was, "The universe does not occur by chance, **God created** the universe according to the Bible" (E20). In both groups, more views seem to be assimilated and suppressed in favour of the Western Science (WS) worldview. A typical WS view expressed was, "... the universe occurred by the **Big Bang theory** and has been scientifically proven" (E6). Overall, both groups appear to subscribe to an equipollent view, appropriately understanding evolution in a scientific/ indigenous worldview. A typically equipollent view was, "**God** the almighty made the universe through the **Big Bang** explosion" (E5).

Student E20 indicated religion as the source of understanding, aligning with the indigenous worldview based on traditional beliefs. Student E6 indicated that his source of understanding is from books. The overall dominant indigenous knowledge worldview expressed by the students seems to be mostly based on their religious beliefs.

Table 4.1.2: Frequency of students' responses to hysteria phenomenon in terms of CAT categories

CAT category	Experimental group		Control group	
	Western Science	**Traditional Knowledge**	**Western Science**	**Traditional Knowledge**
	(Pre) Post	**(Pre) Post**	**(Pre) Post**	**(Pre) Post**
Dominant: expresses a dominant worldview	(7) 7	(9) 11	(4) 12	(5) 9
Suppressed: imitates a worldview at the expense of own worldview	(0) 0	(0) 2	(0) 4	(0) 0
Assimilated: abandons own worldview & adapts new worldview	(0) 1	(0) 3	(0) 4	(0) 2
Equipollent: holds both worldviews & expresses what is deemed appropriate for a given context	(1) 2	(3) 8	(1) 3	(2) 2
Total	**(8) 10**	**(12) 24**	**(5) 23**	**(7) 13**

Note: $N_{experimental}$ = 26; $N_{control}$ = 26; (pre-test f) post-test f

b) Hysteria item. Table 4.1.2 reflects the students' responses to Question 2; their personal and scientific understanding of a girl suffering from severe hysteria, who could not be healed by a western science medical doctor, but was cured by an African traditional healer. The data in Table 4.1.2 suggest that the control group expressed an overall Western Science worldview. A typical Western Science response was, "A **medical doctor** can give [administer] medication to calm her, but a **psychiatric** doctor can help cure it forever, working with small doses of medication ..." (C2). On the other hand, the experimental group seems to hold an overall indigenous knowledge worldview. A typical TK response was, "**Sangomas** [African traditional healers] can cure everything [illnesses] with their natural herbs and can heal you completely" (E11). Both groups expressed some equipollent views e.g., "**Medical** doctors were given the gift to heal people by **God**" (C12) and "**Medical** doctors go to school for these things [medicine] and change herbs into the form of **pills** [tablets]" (E17).

Student E11 demonstrated a Traditional Knowledge view, referring to sangomas who use indigenous knowledge practices to heal people. He indicated culture as the source of understanding, aligning it with the indigenous worldview, based on traditional beliefs and probably personal experiences. Student C2 expresses a dominant Western Science worldview and his source of understanding was media. The data in Table 4.1.2 indicate that the E-group probably experienced a cognitive shift from the Western Science worldview to the Traditional Knowledge worldview. Many students did not respond to this question in the pre-test, suggesting that they probably did not knew what this phenomenon (illness) is.

Table 4.1.3: Frequency of students' responses to rainbow phenomenon in terms of CAT categories

CAT category	Experimental group		Control group	
	Western Science	**Traditional Knowledge**	**Western Science**	**Traditional Knowledge**
	(Pre) Post	**(Pre) Post**	**(Pre) Post**	**(Pre) Post**
Dominant: expresses a dominant worldview	(7) 14	(10) 15	(4) 11	(5) 7
Suppressed: imitates a worldview at the expense of own worldview	(0) 3	(0) 3	(0) 2	(0) 2
Assimilated: abandons own worldview & adapts new worldview	(0) 5	(0) 1	(0) 6	(0) 1
Equipollent: holds both worldviews & expresses what is deemed appropriate for a given context	(0) 2	(2) 2	(1) 2	(1) 1
Total	**(7) 24**	**(12) 21**	**(5) 21**	**(6) 11**

Note: $N_{experimental}$ = 26; $N_{control}$ = 26; (pre-test f) post-test f

c) Rainbow item. Table 4.1.3 reflects the students' responses to Question 3, based on their personal and scientific understanding of the formation and significance of the rainbow. The data in Table 4.1.3 indicate that although the experimental and control group expressed an overall Western Science worldview. A typical WS response was, "Rainbow occurs when light rays from the sun **bend through raindrops** spreading it into different colours" (E6). However, the experimental group had a relatively higher frequency of TK responses, a typical example was, "The rainbow reminds us of **God's promise** that there will never be a worldwide flood again" (E11). The frequency of the equipollent responses is relatively low; a typical equipollent response was, "... **refractive dispersion** by the bending of sunlight through droplets is caused by **God**" (E16).

Student E11 provides religion as the source of understanding, aligning it with traditional beliefs. Student E6's source of understanding is school, giving an explanation that is part of the high school syllabus. The equipollent response of student E16 refers to 'refraction' and 'bending of sunlight through droplets' showing WS conception, but then connects it to a religious view; that 'God' is a power source, causing the phenomenon.

Table 4.1.4: Frequency of students' responses to lightning phenomenon in terms of CAT categories

CAT category	**Experimental group**		**Control group**	
	Western Science	**Traditional Knowledge**	**Western Science**	**Traditional Knowledge**
	(Pre) Post	**(Pre) Post**	**(Pre) Post**	**(Pre) Post**
Dominant: expresses a dominant worldview	(8) 10	(9) 13	(6) 11	(7) 12
Suppressed: imitates a worldview at the expense of own worldview	(0) 2	(0) 3	(0) 2	(0) 1
Assimilated: abandons own worldview & adapts new worldview	(0) 3	(0) 2	(0) 6	(0) 1
Equipollent: holds both worldviews & expresses what is deemed appropriate for a given context	(1) 3	(2) 6	(1) 2	(1) 1
Total	**(9) 18**	**(11) 24**	**(7) 21**	**(8) 15**

Note: $N_{experimental}$ = 26; $N_{control}$ = 26; (pre-test f) post-test f

d) Lightning item. Table 4.1.4 reflects the students' responses to Question 4, based on their personal and scientific understanding of lightning. The data in Table 4.1.4 indicates that the experimental group expressed an overall indigenous knowledge worldview. A typical TK conception was, "In our culture, we sometimes believe lightning occurs when **witches** fight with each other” (E17). The control group seems to express an overall western science worldview e.g., “Lightning is a sudden **electrostatic discharge** that occurs typically during a thunderstorm” (E19). The experimental group provided more equipollent views than the control group and they appear to be generally biased towards the indigenous knowledge worldview e.g., “...lightning can be predicted and explained by **scientists** and is controlled by **God**” (E8).

The experimental group produced a relative high frequency of Traditional Knowledge responses. In my view, the high frequency of responses could be attributed to the fact that South Africa experiences a high number of thunderstorms and lightning (Hlazo, 2015), and many students are from lightning-prone regions in the country.

e) Interpretive summary. Tables 4.1.1 – 4.1.4 show the complexity of human thought in understanding natural phenomena. It reveals that the experimental group appears to have an overall indigenous knowledge worldview, except for Question 3 – the formation of the rainbow. Conversely, the control group seems to have an overall western science worldview, except for Question 1 – the creation of the universe. Furthermore, the Tables exemplifies the perceptual shift in worldviews after the students encountered the DAAFLIM and TIM interventions. For instance, with few exceptions, the experimental group used more data to support their views (claims) in the post-test, than the control group. For example, “Rainbow occurs when light rays from the sun bend through raindrops spreading it into different colours” (E6) and “Rainbow is caused when light goes through a raindrop” (C20). This illustrates the influence of TAP protocol in the DAAFLIM intervention. Overall, both groups appear to subscribe to an equipollent worldview in valuing the scientific/ indigenous conceptions of the selected natural phenomena. In my view, there is nothing drastically wrong in their stance since no one lives permanently in a scientific world (e.g. Aikenhead, & Elliot, 2010; Gunstone & White, 2000; Ogunniyi, 2011). In their criticism of the conceptual learning theory, Gunstone & White (2000) contend that what is important is not for students to replace their indigenous beliefs with the scientific belief but to know what worldview is appropriate for a given learning context. However, the frequency of equipollent views and quality of responses were greater in the experimental group, suggesting that the DAAFLIM intervention they received assisted them to evaluate their responses more critically.

Researchers pointed out that the prior knowledge of indigenous students may actually conflict with western science (Aikenhead, 2006; Baker & Taylor, 1995; Cobern, 1996). For example, Cobern (1996) asserts that the construction of knowledge involves interpretation influenced by prior knowledge. Therefore, we should not expect African students to understand Western and Eurocentric-science exactly the way students in western countries understand science. The African student will construct a view of science based on an African understanding of human beings and the essence of the natural world, which does not mean that that view is unscientific (Cobern, 1996, p. 304).

4.2.2 What conceptions of selected NOS tenets did E-group and C-group students hold before and after experiencing DAAFLIM and TIM respectively?

In regards to this theme, the students had to state whether they support the NOS tenets and provide their explanation in response to questions 5 - 11 in the NOIKS-Questionnaire.

Theme 2:

Question 5 – **Empirical tenet**: Science tells us the truth about the natural world.

Question 6 – **Empirical tenet**: Scientific knowledge is trustworthy, because it has been proven in experiments.

Question 7 – **Universal tenet**: Scientific facts can be tested and every test should produce the same result everywhere.

Question 8 – **Societal tenet**: In scientists' work, socio-cultural (society) and psychological (mind) frameworks play a very important role.

Question 9 – **Societal tenet**: The truth of science is the same for everybody. It does not depend on anyone's personal beliefs or situation.

Question 10 – **Universal tenet**: There is a step-by-step procedure for doing all scientific investigations.

Question 11 – **Subjectivity tenet**: When the results of a demonstration experiment carried out by a lecturer are unexpected and do not confirm the theory, she/ she should adjust them in order to confirm the theory.

Tables 4.2.1 – 4.2.4 show the frequencies of the responses of the experimental group and the control group in terms of the Nature of Science (NOS) tenets. The highlighted (bold) terms in the students' responses were used to classify the students' responses according to a particular thought system.

Table 4.2.1: Frequency of students' responses to the empirical tenet in terms of CAT categories

	Experimental group		Control group	
CAT category	**Western Science**	**Traditional Knowledge**	**Western Science**	**Traditional Knowledge**
	(Pre) Post	**(Pre) Post**	**(Pre) Post**	**(Pre) Post**
Dominant: expresses a dominant worldview	(10) 11	(9) 13	(6) 14	(7) 10
Suppressed: imitates a worldview at the expense of own worldview	(1) 5	(0) 3	(0) 1	(0) 1
Assimilated: abandons own worldview & adapts new worldview	(0) 1	(0) 2	(0) 2	(0) 2
Equipollent: holds both worldviews & expresses what is deemed appropriate for a given context	(1) 3	(2) 5	(1) 2	(1) 4
Total	**(12) 20**	**(11) 23**	**(7) 19**	**(8) 17**

Note: $N_{experimental}$ = 26; $N_{control}$ = 26; (pre-test f) post-test f

a) Empirical tenet. Table 4.2.1 reflects the students' responses to Question 5; "Science tells us the truth about the natural world" and Question 6; "Scientific knowledge is trustworthy because it was proved in experiments". The data in Table 4.2.1 reveals that the control group expressed a dominant Western Science worldview. A typical response agreeing with this NOS statement was, "Science can explain everything, for example, **Newton's laws** explain how things move" (E22). The experimental group appear to express an overall Traditional Knowledge worldview. A typical response disagreeing with this NOS statement was, "There are some sicknesses which the western science cannot explain and cure, like mental illnesses which **traditional healers** can treat" (C6). The equipollent responses in both groups increased in the post-test. A typical equipollent response was: "The natural world is complex and difficult to understand, that's why we need to make use of western science and traditional knowledge to understand many things, like **viruses** and **ghosts**, but everything cannot be explained by western science" E10. The most equipollent views appear to be biased towards Traditional Knowledge worldview.

Table 4.2.2: Frequency of students' responses to societal tenet in terms of CAT categories

CAT category	Experimental group		Control group	
	Western Science	Traditional Knowledge	Western Science	Traditional Knowledge
	(Pre) Post	(Pre) Post	(Pre) Post	(Pre) Post
Dominant: expresses a dominant worldview	(8) 13	(9) 10	(10) 14	(7) 9
Suppressed: imitates a worldview at the expense of own worldview	(0) 2	(0) 1	(0) 1	(0) 2
Assimilated: abandons own worldview & adapts new worldview	(0) 3	(0) 2	(0) 2	(0) 1
Equipollent: holds both worldviews & expresses what is deemed appropriate for a given context	(3) 4	(1) 3	(2) 2	(1) 2
Total	**(11) 22**	**(10) 16**	**(12) 19**	**(8) 14**

Note: Nexperimental = 26; Ncontrol = 26; (pre-test f) post-test f

b) Societal tenet. Table 4.2.2 reflects the students' responses to Question 8: "In their work, scientists are influenced by their socio-cultural and psychological frameworks" and Question 9: "The truth of science is the same for everybody. It does not depend on anyone's personal beliefs or situation". The data in Table 4.2.2 indicate that a dominant Western Science conception is probably maintained for both groups in both the pre-test and the post-test for this NOS statement. A typical response agreeing with this NOS tenet was, "Scientists **must not** [allow] that their personal feelings interfere with the experiments, because that will influence the results” (C9). Those students who disagreed with this tenet typically responded: “the sangomas show **emotions and sing** and worship while they treat people” (E15). There appear to be a greater increase in equipollents views in the experimental group, than in the control group. A typical equipollent view was, “When a western **scientist** works in a traditional community he must respect and obey the **tradition** of the tribe, when he is doing his work” E20.

Table 4.2.3: Frequency of students’ responses to universal tenet in terms of CAT categories

CAT category	Experimental group		Control group	
	Western Science	**Traditional Knowledge**	**Western Science**	**Traditional Knowledge**
	(Pre) Post	**(Pre) Post**	**(Pre) Post**	**(Pre) Post**
Dominant: expresses a dominant worldview	(8) 11	(9) 15	(10) 14	(7) 8
Suppressed: imitates a worldview at the expense of own worldview	(0) 1	(0) 2	(0) 1	(0) 2
Assimilated: abandons own worldview & adapts new worldview	(0) 1	(0) 1	(0) 2	(0) 1
Equipollent: holds both worldviews & expresses what is deemed appropriate for a given context	(1) 3	(1) 3	(2) 3	(1) 2
Total	**(9) 16**	**(10) 21**	**(12) 20**	**(8) 13**

Note: Nexperimental = 26; Ncontrol = 26; (pre-test f) post-test f

c) Universal tenet. Table 4.2.3 reflects the students’ responses to Question 7: “Scientific facts can be tested and every test should give the same result everywhere” and Question 10: “There is a step-by-step procedure for doing all scientific investigations”. The data in Table 4.2.3 indicate that the experimental group’s overall responses appear to be aligned with the Traditional Knowledge conception e.g.: “**Traditional** healers do not always come up with the same result, for example, many people are not healed with the same herbs and same treatment” (E5). The control group seems to expressed an overall Western Science worldview e.g.: “Scientists all over the world **will have** the same results for specific experiments, like determining whether a horizontal beam is in equilibrium by doing calculations” (C11). The equipollent responses for both groups increased in the post-test and typically responded: “The farmers with modern

scientific farming equipment follow the same processes to plant mealies than my [traditional] family who do it by **hand**, and produce a harvest" (C7).

Table 4.2.4: Frequency of students' responses to the subjective tenet in terms of CAT categories

	Experimental group		Control group	
CAT category	**Western Science**	**Traditional Knowledge**	**Western Science**	**Traditional Knowledge**
	(Pre) Post	**(Pre) Post**	**(Pre) Post**	**(Pre) Post**
Dominant: expresses a dominant worldview	(10) 15	(8) 11	(9) 12	(7) 10
Suppressed: imitates a worldview at the expense of own worldview	(0) 2	(0) 2	(0) 2	(0) 1
Assimilated: abandons own worldview & adapts new worldview	(0) 3	(0) 1	(1) 2	(0) 1
Equipollent: holds both worldviews & expresses what is deemed appropriate for a given context	(2) 4	(1) 3	(2) 3	(1) 1
Total	**(12) 24**	**(9) 17**	**(12) 19**	**(8) 13**

Note: Nexperimental = 26; Ncontrol = 26; (pre-test f) post-test f

d) Subjective tenet. Table 4.2.4 reflects the students' responses to Question 11, "When the results of a demonstration experiment carried out by a lecturer are unexpected and do not confirm a particular theory, she should adjust it in order to confirm that theory". The data in Table 4.2.4 indicated that the experimental group and the control group expressed a Western Science worldview. A typical WS response was; "The same experiment **cannot have** two different results, there is something wrong, the right steps are not followed" (E7). A typical TK views was, "The same medication has sometimes **different effects** on different people, scientists must treat each case in context, because each one [person] is unique" (E12). The Table also reflects a relatively high number of equipollent responses e.g., "When I have the flu I sometimes take a **pill** and sometimes I use **herbs** from the garden and both take away my flu" (E20).

e) Interpretive summary. The experimental and control group appear to expressed an overall dominant Western Science conception for all the Nature of Science (NOS) tenets with the exception of the Empirical and Universal tenets responses of the experimental group. Tables

4.2.1 – 4.2.4 indicate that the experimental group has a higher equipollent frequency than the control group, suggesting that the experimental group students seem to hold both worldviews and are able express the NOS tenets confidently with the appropriate context. This could probably be attributed to the DAAFLIM experienced by the E-group. Self-assessment strategy might have assisted the students to make sense of the questions and their answers to relate it to previous knowledge, and to reflect critically on the possible outcomes. Furthermore, the ability of argumentation during the DAAFLIM lesson activities could have enhanced students' awareness and understanding of the differences and similarities between TK and NOS. In this regard, students may be in a better position to appropriate knowledge claims and use whichever is appropriate, as the context requires.

4.3 Research Question 2: Students' biographics and DAAFLIM

Are the E-group's conceptions of the selected topics related to their age, gender or cultural backgrounds?

This research question puts the study in perspective and contextualizes the background of the participants by looking at their biographical data by relating them to their achievement in the Science Achievement Test (SAT). Many educators teach students if they are the same and have similar backgrounds, unaware of the diverse backgrounds. However, literature show that biographic and socio-cultural factors influence the way in which students learn (Cobley, McKenne, Baker & Wattie, 2009; Greenfield, 1997; Jones, Howe & Rua, 2000; Lee & Burkam, 1996). The next section tabulates each biographic variable related to the students' achievement scores in the post-test of SAT.

4.3.1 Did gender difference influence the performance of the E-group? The analysis of the data, based on gender across the experimental and control groups using the post-test scores produced the following results. Table 4.3.1 indicates that the female students with a mean score of 18.4 performed slightly better compared to the male students who had a mean score of 17.4. However, the t-statistics ($t_{observed} = 0.751$; $t_{critical} = 2.02$; $p < 0.05$) do not show a significant difference between the gender groups.

Table 4.3.1: Students' achievement according to gender

Gender	N	Mean	SD	t - value	Sig. (2-Tailed)
Female	25	18.4	4.47	0.751	0.456
Male	27	17.4	5.01		

Note: $t_{critical}$ = 2.02; df = 50; p = 0.05

It is a general observation that female students perform better than male counterparts do, in most learning programs at the TVET College. Several studies indicate differences in performance in science and interest in science based on gender, especially in engineering studies (Greenfield, 1997; Jones, Howe & Rua, 2000; Lee & Burkam, 1996). These studies suggest that female students perform better in science, despite a perception that subjects like mathematics and engineering sciences are viewed as 'masculine', and subjects such as biological sciences, languages and art are viewed as 'feminine'. In a large-scale study involving over 6 000 students from all nine provinces in South Africa, female students consistently outperformed their male counterparts on topics like energy and change, including chemical reactions and several other concepts (Lee & Burkam, 1996; Leedy, Lalonde & Runk, 2003; Ogunniyi, 1999; 2003). Bricker & Bell (2008) and Geer & Sweeney (2012) assert that male students performed significantly better than females in engineering science, contradicting the findings above. They argue that engineering is a male-inclined to occupational field because it requires excessive physical strength to move machinery in many cases.

4.3.2 Did age difference influence the performance of the E-group? Table 4.3.2 indicates that older students performed better than their younger counterparts, with a mean score difference of 1.14. However, the t-statistics show that there is no significant difference ($t_{observed}$ = 0.835; $t_{critical}$ = 2.02; $p < 0.05$) between the two age groups in this study. A different trend was observed in the large-scale study alluded to above of Ogunniyi (1999, 2003) where younger students performed better. In Ogunniyi's study, the better performance of the younger students during the activity sessions is due to the younger students' eagerness and attentiveness than their seniors, who seemed to be joking or bored, and even posed disciplinary challenges to the educator.

Table 4.3.2: Students' achievement according to age

Age	**N**	**Mean**	**SD**	**t - value**	**Sig. (2-Tailed)**
≤ 20 years	31	17.34	4.50	0.835	0.408
> 20 years	20	18.48	5.11		

Note: $t_{critical} = 2.021$; df = 48; p = 0.05

There are also studies that support the results of Table 4.3.2, suggesting that older students perform slightly better when engaging with the same content material than younger students (Cobley et al., 2009; Greenfield, 1997; Hendricks, 2001). Hendricks (2001, p. 102) asserts, "Age does play a significant role in determining the participants' understanding of science concepts because maturity brings along experience". Cobley et al. (2009) agree with Hendricks' assertion, "Strong evidence suggests that subtle age differences between students in the same year of study contribute to varying levels of attainment between students, irrespective of gender, stage of education, subject or type of assessment examined". They further found the older students' attainment to be significantly higher than the younger students did. With the measure of this discrepancy appearing to be greatest during the initial stages of study at an institution, as much as 10%, and declining in the latter years of study of the students.

4.3.3 Did race difference influence the result of the E-group? The apartheid policies of South Africa prior to 1994 discriminated in terms of culture, language, education and ethnicity or 'race'. In the process of applying apartheid education policies, Whites, Africans, 'Asians' and Coloureds were systematically isolated physically and culturally (Fataar, 2007). This resulted in acculturation - an individual becomes adapted to a new culture (apartheid) which caused social and psychological distance between the cultural groups (Dinie, 2000). Isolation enabled the Apartheid education system to operate parallel, but distinctly unequal race-based education administrations, each with its own objectives, infrastructure, funding and curricula. The racial discrimination of the apartheid education system aimed at preparing Blacks for the apartheid 'labour' market, through a curriculum encouraging knowledge transmission and rote learning (Kallaway, 1984). Education for Whites were compulsory, free and resourced with state funding.

Black education, on the other end, suffered from the consequences of insufficient provision, inadequate funding, curriculum deficiencies, insufficient educator training; as well as overworked, underpaid and unmotivated teachers (Swanepoel & Booysen, 2003). The Apartheid education system had to reproduce generations of compliant black workers and cooperative white masters with the assistance of a repressive legal system, cooperative judiciary and a vicious security apparatus. These are evidential historical factors when discussing race in the current South African education context.

Post 1994, the education system was subjected to several reforms to redress the inequality and inequity of the apartheid system. These reforms acknowledged the need to transform the pedagogy and methodologies used in classrooms, immediately impacted on institutional resourcing. The apartheid government allocated more education resources to the Coloured cultural group than to Africans. Furthermore, White schools and colleges received more education resources than the rest of the South African population. However, the post-apartheid government had to share the education resources nominally and 'equitably' among all cultural groups, but the apartheid status quo of resource distribution at the previously advantaged and previously disadvantaged institutions largely prevails. Therefore, after 1994 huge numbers of African students enrolled into historically Coloured and White institutions, including TVET colleges. Against this backdrop, the performance of African and Coloured students in this study raises interesting possibilities of interpretation.

Table 4.3.3 indicates that the African students performed better than the Coloured students did with mean scores of 19.5 and 17.2 respectively, however, there is no statistically significant difference ($t_{observed}$ = 1.54 and $t_{critical}$ = 2.02 at $p < 0.05$) between the two groups.

Table 4.3.3: Students' achievement according to race

Race	N	Mean	SD	t - value	Sig. (2-Tailed)
Coloured	14	17.24	4.146	1.542	1.30
African	35	19.50	5.701		

Note: $t_{critical}$ = 2.021; df = 48; p = 0.05

The African students probably worked much harder to prove themselves equal to, or better than the Coloured students did, who was used to the resources at the historically advantaged TVET College. In my view, the Coloured students appeared to take the educational opportunities, to which they had easy access, for granted and became complacent. However relevant this issue, it was not a central concern of this study and warrants a more detailed investigation in future studies.

4.3.4 Interpretive summary. The analysis of the performance scores of the students based on age, gender and race contextualizes the responses of the participants. The results indicate that the female students performed slightly better than the males in understanding the selected science concepts, but the difference was not statistically significant. This finding accords with Bricker & Bell (2008), concluding that females generally perform better than males in the initial years of study, and males outperform females in the final years of study. The results in terms of age difference indicated that older participants performed slightly better than their juniors did. Hendricks (2001) asserts that the performance gap between the age groups shrinks in the final years of study. The analysis in terms of cultural groups suggests that the African students performed marginally better than the Coloured students did; however, the difference is not statistically significant.

4.4 Research Question 3: The DAAFLIM and TIM interventions

Are conceptions of SI-units, dynamics, statics and energy (henceforth, selected science topics) held by the E-group and C-group students significantly different before and after being exposed to DAAFLIM and TIM respectively?

In answering this research question, the comparability of the two groups was established. Thereafter, the pre-test and post-test responses of the Science Achievement Test (SAT) were analysed to determine whether or not conceptual changes took place in the experimental and control groups. The post-test scores of the Science Achievement Test were analysed to determine the effectiveness or otherwise of the Dialogical Argumentation and Assessment for Learning Instruction Model (DAAFLIM) intervention strategy. The discussion of the results takes place through the analytic lenses of the Contiguity Argumentation Theory (CAT), Toulmin's Argumentation Pattern (TAP) and zone of proximal development (ZPD). The DAAFLIM intervention experienced by the E-group demonstrated the applicability of the three theoretical constructs (CAT, TAP and ZPD).

4.4.1 Comparability of the groups before the study. It was necessary to establish the comparability of the groups in terms of their preconceptions on the selected scientific concepts. The SAT pre-test results of the E-group and the C-group gave an indication of the comparability before the study. Table 4.4.1 illustrates the results obtained using the two-group t-test for independent samples and the comparison of the total scores of the groups in the pre-test (Field, 2009).

Table 4.4.1: Comparing pre-test scores of the experimental and control group on the SAT

Group	N	Mean	SD	t-test	Sig (2-tailed)
Experimental group	26	8.37	2.76	1.217	0.229
Control group	26	7.42	2.83		

Note: $t_{critical} = 2.02$; $p = 0.05$; $df = 50$

The pre-test results show that the difference between the mean scores (8.37 and 7.42) and the standard deviations (2.76 and 2.83) for the experimental and control groups are very small. The t-ratio value of 1.217 is less than the t-critical value of 2.02 at $p < 0.05$, indicating that the null hypothesis, which expected significant differences between the groups, can be rejected. Therefore, no statistically significant difference between the groups at the pre-test stage of the study, suggest the comparability of the two groups. However, one can assume that both groups probably had had some understanding of the selected concepts because the groups scored a percentage average of 27% and 24% respectively in the pre-test.

Similarities in the pre-test scores of the E-group and C-group could be attributed to the traditional instructional practices they received before the commencement of the study. A further analysis of the pre-test results in Table 4.4.2 indicates that, for all the items tested, there were no statistical significant differences found. This supports the assumption that the groups were comparable at the pre-test stage. Table 4.4.2 also indicates that the students scored the lowest in Question 3, which assessed the concept of moment forces acting on a horizontal beam

Table 4.4.2: Pre-test scores per item on the SAT

Concepts	Group	Mean	SD	t-value	Sig.(2-tailed)
Question 1:	Experimental	2.79	1.27	1.962	0.055
SI-units & Conversions	Control	2.15	1.04		
Question 2:	Experimental	2.31	0.91	0.801	0.023
Dynamics (graph)	Control	2.23	1.26		
Questions 3:	Experimental	0.48	0.92	-0.784	0.437
Statics (Beam)	Control	0.69	1.02		
Question 4:	Experimental	2.04	1.64	-0.637	0.527
Energy	Control	2.35	1.84		
Total	Experimental	**8.37**	**2.76**	**1.217**	**0.229**
	Control	**7.42**	**2.83**		

Note: The $t_{critical} = 2.02$; $p = 0.05$; $df = 50$; $N_{control\ group} = 26$; $N_{experimental\ group} = 26$

The highest scores were achieved in Question 1 by the E-group, where students had to recall and convert SI-units of quantities. Question 4 attracted the highest score in the control group, testing their knowledge of Energy. The reason for the high scores in Questions 1 and 4 could be that the students had dealt with these concepts in their previous science course. Figure 4.1 indicates the comparison of the control and experimental in terms of their results per item in the pre-test.

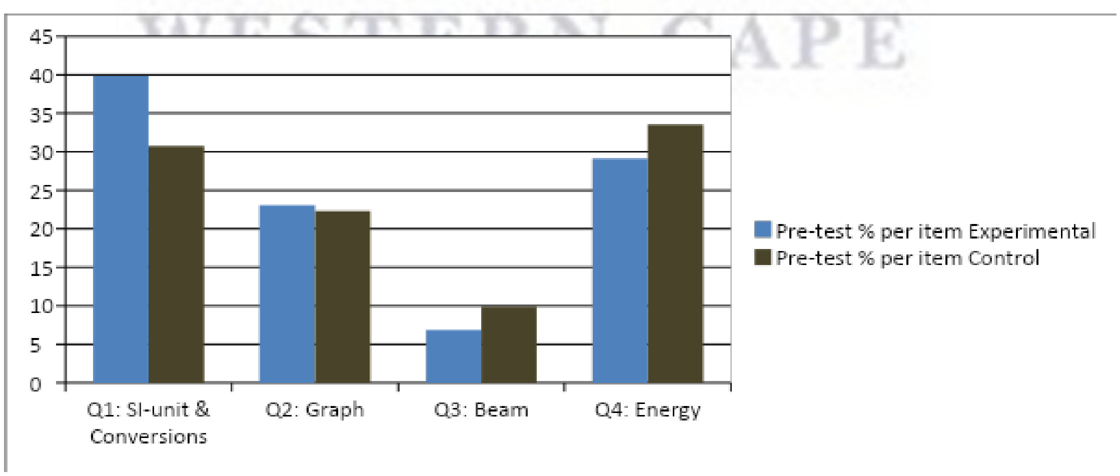

Figure 4.1: Pre-test percentage per item of the SAT

Typical responses in the pre-test, indicating that most concepts were new to the students, were:

Question 1 (SI-units and Conversions): Student E5 provided the SI-unit of acceleration as "m/s" instead of m/s^2 (Question 1.1.1). Student E7 multiplied instead of dividing the 0,065 m by a hundred to convert it to centimeters (Question 1.2.1). Student E19 did not do any calculations, she probably assumed that the mass and weight is the same quantity, only the units differ, giving the weight as 45 N and the mass as 45 kg (Question 1.3.1). Some of the students were not aware that the Moon has a lesser gravitational force than planet Earth (Question 1.3.2).

Question 2 (Interpreting graphs of motion): Student E6 drew a straight-line graph from the origin without showing the constant velocity part (horizontal line) on the velocity-time graph. Student E4 drew the correct graph without a title and labels. Student E9 had a correct graph with incorrect labels. Student E21 plotted the points incorrectly on the axis system.

Question 3 (Moments on a horizontal beam): Student E5 could not determine the distance between the concentrated load force and fulcrum for most of the moments. Student E7 explained that: "a chair does not exert any force on you when you sit on it because there is no movement". Student E18 identified the direction of the moment forces wrongly, anti-clockwise instead of clockwise. Student E20 could not prove that the horizontal beam was in equilibrium by showing that the sum of the upward forces was equal to the sum of the downward forces, applying Newton's third law of motion. Many students did not answer this question, especially the last part where they had to determine the vertical component of a vector.

Question 4 (Energy): The majority of the students could calculate the gravitational potential energy of the stationary brick at the top, before being released, but were unable to determine the velocity of the falling brick just before it reached the ground. However, the majority were able to differentiate between the definition of the gravitational potential energy and kinetic energy of the falling brick.

4.4.2 Comparing the pre-test and post-test responses. Table 4.4.3 reflects the pre-test and post-test scores obtained by the experimental and control groups in the SAT.

Table 4.4.3: Comparing the pre-test and post-test scores on the SAT

Statistics	Experimental Group			Control Group		
	Pre-test	**Post-test**	**Diff.**	**Pre-test**	**Post-test**	**Diff.**
Mean	8.4	19.8	17.4	7.4	15.9	9.0
SD	2.76	4.46	1.70	2.83	4.23	1.40
t-test	11.170*			8.512*		

Note: $t_{critical} = 2.02$; $p = 0.05$; $df = 50$; $N_{control\ group} = 26$; $N_{experimental\ group} = 26$; * = statistically significant

The null hypothesis, which expected no statistically significant differences between the pre-test and post-test scores of the E-group, can be rejected because the t-ratio value of 11,17 is greater than the t-critical value of 2.02 at $p < 0.05$. This indicates a statistical difference between the pre-test and post-test results of the E-group. The t-test results indicate a significant change in the means of the pre-test and the post-test. Thus, it is safe to assume that the E-group improved its understanding of the selected concepts in the SAT considerably. The assumption is that the DAAFLIM intervention improved the students' understanding in the E-group.

As in the case of the experimental group, there was a statistically significant difference between the pre-test and post-test scores of the control group, as reflected in Table 4.4.3. There was also a significant increase in the means from the pre-test to the post-test. The difference between the pre-test and post-test mean scores for the experimental group is 17.4 (56%) and for the control group is 9.0 (29%), indicating that the experimental group experienced greater conceptual improvement. Although the experimental group outperformed the control group with a difference in the post-test scores of 3.93 (13%), it is noteworthy that the control group also improved with 9.0 (29%). Thus, the traditional instructional method used in the control group also produced an improvement in the performance of the group relative to the selected concepts, but to a lesser extent than the experimental group.

The mean is a useful statistic for measuring the concept of average in a distribution. It measures the values of each score in a distribution and forms an important component in interpreting central tendency. However, it is very sensitive and easily affect extreme scores in a distribution. Hence, for ease of reference and avoiding interpretation errors, it is better to convert mean scores into percentages (Ogunniyi, 1984b). The mean values of the pre-test for the experimental group (8.37) and the control group (7.42) suggest that there was no difference at the start of the study. However, the post-test mean scores suggest a significant difference in the scores of 3.93 (13%). The smaller standard deviation of the pre-test and the bigger standard deviation of the post-test of both groups indicate there was a greater variability at the post-test stage.

4.4.3 Comparing the groups after the study. Table 4.4.4 reflects the post-test results of the experimental and the control group, revealing a t-ratio value of 3.253 obtained against a t-critical value of 2.02 at $p < 0.05$. Thus, the null hypothesis expecting no statistically significant difference between the two groups is rejected. This indicates that the DAAFLIM instructional method used in the experimental group classroom is more effective than the traditional expository method of instruction used in the control group classroom.

Table 4.4.4: Comparison of the post-test scores of the groups in the SAT

	N	Mean	SD	t-test	Sig (2-tailed)
Experimental group	26	19.85	1.49	3.253*	0.550
Control group	26	15.92	1.41		
Difference		3.93	0.08		

Note: $t_{critical} = 2.02$; $p = 0.05$; $df = 50$; $N_{control\ group} = 26$; $N_{experimental\ group} = 26$; * = statistically significant

Further comparison of the pre-test and post-test results in terms of the selected concepts reveals additional information about the change in performances of the groups from the pre-test to the post-test stage, as indicated in Table 4.4.5.

Table 4.4.5: Scores per item in pre-test and post-test in the SAT

Item	Group	Pre-test	t-value	Post-test	t-value
Question1: SI-unit & Conversions	Experimental	2.79	1.962	4.67	1.587
	Control	2.15		4.04	
Question2: Dynamics (Graphs)	Experimental	2.31	0.801	5.60	3.244*
	Control	2.23		4.29	
Questions 3: Statics (Beams)	Experimental	0.48	-0.784	4.67	2.409*
	Control	0.69		3.17	
Question 4: Energy	Experimental	2.04	-0.637	5.25	2.058*
	Control	2.35		4.42	
Total	Experimental	**8.37**	**1.217**	**19.85**	**3.253***
	Control	**7.42**		**15.92**	

Note: $t_{critical}$ = 2.02; p = 0.05; df = 50; $N_{control\ group}$ = 26; $N_{experimental\ group}$ = 26; * = statistically significant

Table 4.4.5 compares the students' performance in the pre-test and the post-test per item in the SAT. The performances of the students range from 4.67 to 5.60 for the experimental group and 3.17 to 4.42 for the control group at the post-test stage. Figure 4.2 indicates the comparison between the control and the experimental group in terms of their results in the pre- and post-test of the SAT.

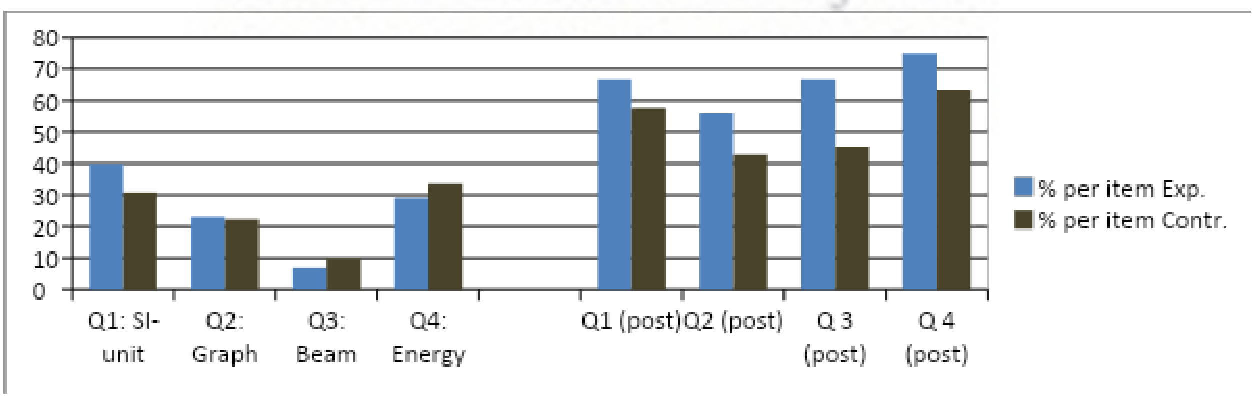

Figure 4.2: Experimental and control group post-test percentage per item

Question 3 (Statics), requiring students to calculate the moments of forces acting on a horizontal beam, attracted the least valid responses for both groups in the pre-test. This suggests that the students found it very difficult to answer this question compared to the other questions at the start of the study. In the pre-test, the experimental and control groups scored 7% and 10% respectively for Question 3, suggesting that the students related poorly to applying the law of moments at the start of the study. The performance for this question improved to 45% (control) and 67% (experimental) respectively, suggesting substantial improvement. In Question 2 (Dynamics), requiring the interpretation and calculations of a graph of motion, both groups scored the least in the post-test, suggesting that it was the most difficult concept to master.

In the pre-test, the experimental group had the most valid responses (40%) in Question 1, requiring students to mainly recall and convert SI-units of physical quantities. On the other hand, the control group had the most valid responses (31%) in Question 4, dealing with conservation of energy. In the post-test, both groups had the most valid responses in Question 4 (Energy), 75% (experimental) and 63% (control) respectively. This indicates that the control group had a consistent dominant conception of Energy, in the pre-test and post-test, in comparison to the other concepts. The best improvement from the pre-test to the post-test was shown for Questions 3 (Statics) for both groups, 60% (experimental) and 35% (control) respectively. This is probably because more time was spent on Statics (Moments), involving more emergent sub-concepts (Newton's laws of motion, torque and components of a force) compared to the other sections. However, it is interesting that the question attracting the most valid responses from both groups in the post-test was Question 4 (Energy). This could be because the Energy section consisted of low-level knowledge questions (Bloom, 1956). The least improvement from the pre-test to the post-test for the experimental group was seen in Question 1 (27%) and for the control group was Question 2 (19%).

4.4.4 E-group observation and DAAFLIM

a) E-group classroom observation. The educator arranged the desks of the students into six clusters during all the sessions, making it convenient for group discussions (four students in a group). This arrangement created an AfL-atmosphere where students interact easily with each other during the DAAFLIM activities. The educator followed the DAAFLIM lesson plan for each activity worksheet, requiring students to work individually, in groups and then in a whole-class discussion. He introduced the topics and explained the objectives of the lesson at the start (nodal point) of each lesson. The educator asked the students about their cultural backgrounds and related the topics of the lesson to the western sciences worldview and the indigenous knowledge worldviews (statics – ancient and modern architecture and energy – traditional healing and ability to do work). Thereafter he proceeds to assess the prior knowledge of the students making use of questions-and-answers and Plicker quiz-cards. The Plicker quiz application (as explained in section 3.6.2b) gave the educator immediate and automatic feedback on the students' prior knowledge, which he used to determine the course and pace of the lesson. The educator gave each student an activity sheet to complete individually (intra-argumentation space) in silence for about 10 minutes.

When the students completed the individual worksheets, they join in pairs to discuss each other's responses (think-pair-and-share). The educator emphasized the importance of the question-and-answer techniques (eliciting responses, probing questions, posing open-ended question and 3-second-wait-time) and TAP-protocol (providing claims, counter-claims, supporting data, rebuttals, etc.) that students must use during the discussions. After the think-pair-and-share sessions, the students moved into small groups discussing and reaching group consensus about the worksheet tasks (inter-argumentation space). During the discussions, the students used dialogical argumentation, self-assessment and peer assessment strategies to respond to the questions of the worksheet. These strategies encouraged the students to participate in the classroom activities, formulating their own ideas and to share their thinking with at least one other student. Furthermore, the strategies inspired students to listen to each other's ideas and to understand different viewpoints. During the group work activities, the educator walked amongst the groups and engaged with students individually; and with the different groups, asking probing questions. Students appeared to be relaxed and interacted freely and robustly in their groups.

At the end of the group work session, the educator determined the progress and performance of the students/ group using the Plicker cards for the post-quiz. When the group discussions were completed, the educator facilitated the whole-class discussion (trans-argumentation space). He specifically focused on the students' application of the Toulmin's Argumentation Pattern (TAP) protocol and the achievement of the lesson objectives. During the whole-class discussion, the different groups gave feedback on their consensus responses. The whole class responded to, and interrogated the presentations of the different groups in terms of scientific explanations and the TAP protocol. Thereafter, the educator made the groups aware of the misconceptions and incorrect responses in their feedback and linked it to the lesson objectives (reflective space). The educator played devil's advocate, asking thought-provoking questions randomly to all groups, reflecting on the process of argumentation and conception in each group.

Finally, after each session, the educator collected the completed DAAFLIM activity sheets of each student and the groups for comment marking; and handed them back to the students at the next session (teacher review). Figure 4.3 shows examples of comment marking of correct and incorrect responses, which the educator gave to two different students. Effective feedback depends on task-focused comments, rather than ego-focused comments (Black & Wiliam, 2010). The educator praised students for valid responses, but also point out mistakes, for example, "Great! I can see you understand this, but [you used] a wrong symbol". The educator did not make the strong students complacent, letting them think they did not have anything to do to improve. On the other hand, the comment marking of the incorrect responses give feedback to students indicating and explaining correction, for example, "Wrong formula!" and "You can do better!" It is very important to present feedback as a dialogue, not a monologue (Davies, 2000b).

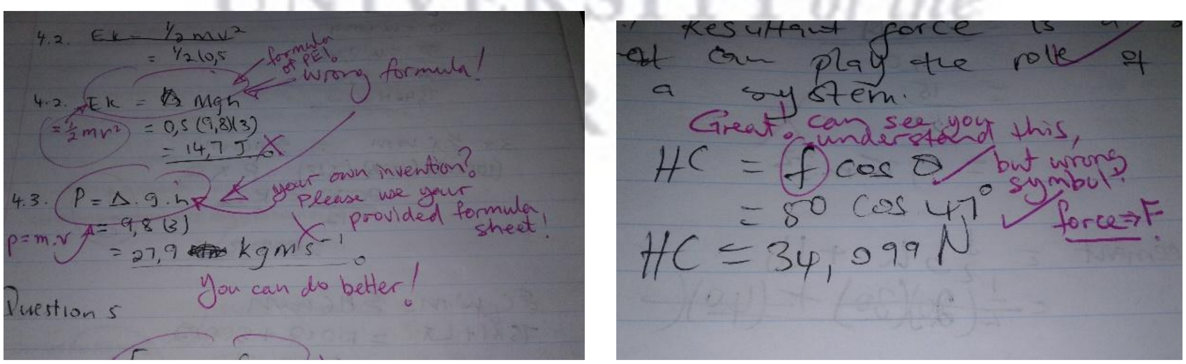

Figure 4.3: Examples of comment marking

The educator gave the students opportunities to request specific feedback during the group work and class discussion sessions. Winstone & Boud (2019) assert that, dialogic activities where the provider of comments entered into a process initiated by students, and concluded by students produce meaningful responses in subsequent work. I agree with this notion and believe that feedback should move beyond the process of justifying a grade, it should be about engaging in dialogue with students about their work. The process of assessing students' work can become more transparent and open, minimizing students' dissatisfaction with the 'fairness' of marking procedures.

In most of the activities, the students in the experimental group enthusiastically took part in the activities and enjoyed the interaction in the classroom. At the end of the study, after the last worksheet activity, the researcher interviewed a focus group. Students in the group responded as follows:

Student E24: "I loved the Plickers quiz; it was interesting to compare myself with the other students and to see what I have learnt. I hope my other lecturers will also let us learn in this way!"

Student E8: "It was nice to work in groups and to share my ideas with others and to hear their views. I understand beams [moments] much better now!"

Student E15: "I have learnt that I cannot just give the first answer that comes in my head, but have to think and give warrants, backings and qualifiers! I feel confident to challenge my friends on science topics. I can reason like a lawyer, Sir!"

Student E10: "I like the fact that Sir makes sure we understand the work; asking lots of questions, before we go to another topic!"

These typical responses can be construed as evidence to show that the lesson activities have enabled the students to gauge and appreciate the usefulness of DAAFLIM.

Mortimer and Scott's (2003) communicative approaches model (explained in Chapter 3, Figure 3.4), determining the teacher-learner-talk ratio and classroom-talk in general, was used to analyze the nature of discourse in the classroom. The results of the observation schedule suggest that the experimental group experienced an interactive-dialogic communicative approach with a teacher-talk: learner-talk: silence ratio of 36:42:22, illustrated in Table 4.4.6.

Table 4.4.6: Patterns of talk in the different groups

	Experimental group (frequency)%	**Control Group (frequency)%**
Teacher-talk	(18) 36%	(29) 58%
Learner-talk	(21) 42%	(16) 32%
Silence	(11) 22%	(5) 10%

Note: $N_{\text{control group}} = 26$; $N_{\text{experimental group}} = 26$

Furthermore, the results also indicate that a student-centred instructional atmosphere was present in the classroom with a teacher-talk: learner-talk ratio of 46:54 (Appendix 13). The communicative approaches model confirms the formative influences of the DAAFLIM during the instruction process, namely: high level of questions-and-answers, quality responses and informative feedback.

b) Further demonstrations of CAT, TAP and ZDP in DAAFLIM. In the science classroom, students construct logical arguments to support their claims. Toulmin's Argumentation Pattern (TAP) use deductive reasoning and formal logic to justify claims and counter-claims. Most DAAFLIM strategies such as questions-and-answers, peer-feedback, think-pair-and-share and educator-facilitation adopted the TAP-protocols to assist students in formulating arguments and providing acceptable justification for their claims. The Contiguity Argumentation Theory (CAT) also assist students and educators with deductive reasoning, but covers non-logical metaphysical reasoning as well, which includes the western and indigenous worldviews. Students were also able to demonstrate that both thought systems co-exist in some equipollent responses. The DAAFLIM strategies classroom discussions, questions-and-answers, group work activities and eliciting evidence of learning provided students scaffolds to transverse the zone of proximal development (ZPD). The following sections illustrates episodes of how E-group students demonstrated the applications of CAT, TAP and ZDP.

The following excerpts of some E-group students illustrating the different categories of CAT:

- **Dominant mental state** (when it is the most adaptable to a given context). Student E7: “A chair does not exert any force on you when you sit on it because there is no movement” (Appendix 9: SAT, Question 3.1, pre-test).

- **Suppressed mental state (**when the dominant cognitive stage is overpowered by another more adaptable mental stage). Student E6: “Okay, I agree. Then my original claim [It is impossible for distance and displacement to be equal] is not always true, it can be the rebuttal” (Appendix 10: Dynamics worksheet, Question 1.5).

- **Assimilated mental state** (when the dominant mental stage is absorbed into another more adaptable mental stage). Student E7: “the chair is pushing you upwards with the same force as your weight” (Appendix 9: SAT, Question 3.1, post-test).

- **Emergent cognitive stage** (when an individual has no previous knowledge of a given phenomenon). Student E19: “The weight of the girl will be less on the Moon, because Earth’s gravity is greater” (Appendix 9: SAT, Question 1.3.2, post-test).

- **Equipollent mental state** (when two competing ideas or worldviews tend to co-exist in the mind of the individual, without necessarily resulting in a conflict). Student E15: “No, energy cannot be created or destroyed, but transferred from one object to another. I also believe that God can create and destroy energy” (Appendix 9: SAT, Question 4.5, post-test).

The following discussion demonstrates how mental shifts took place in terms of CAT. The students' responses also seemed to reveal that mental shifts took place resulting in improved understanding of the concept of conservation of energy. The discussion was about gravitational potential energy, kinetic energy and mechanical energy relating to a load falling from a certain height above the ground (Appendix 12: Energy worksheet, Question 2). The following discussion ensued to reach consensus during a Think-Pair-Share activity:

Student E7: "Let's see what is it that we have to do in this question and compare our answers."

[The students read the question and compares their notes]

Student E5: "When the cable of the crane snaps and the load falls, the potential and kinetic energy increase, because gravity pulls the crane down." ***(Initial dominant view)***

Student E7: "I don't agree with you! Potential energy will decrease because the height becomes less as the load falls down and the speed increases as it falls, therefore the kinetic energy increases." ***(Emerging view for E5)***

Student E5: "Okay, it makes sense. When we use the formulas, potential energy depends on height which decreases; and kinetic energy depends on velocity which increases." ***(Assimilated view)***

In this Think-Pair-Share activity, students discussed where they are in their learning; where they want to be in their learning; and how they are going to master the learning objectives. Moss and Brookhart (2019) asserting that students should become more active in their learning and think like an educator, and to think more actively about where they are, where they are going and how to get there.

The following group discussion illustrates dialogical argumentation between the E-group students and is analysed in terms of the TAP-protocol. The students were discussing, *"Is it possible that distance and displacement can have the same magnitude? Explain your answer"* (Appendix 10: Dynamics worksheet, Question 1.5).

Student E6: "My claim is that: 'It is impossible that the distance and displacement can be the same thing'. If I walk home from school, the distance is the actual path I covered and displacement is the straight-line distance. For example, if I fly in a helicopter from school to home, the distance walked will always be longer than the displacement of the helicopter! What do you think guys?"

Student E8: “Yes, your claim can be true for your example. But it is not always true, because if you just look at the movement of the helicopter, and take the distance and displacement of the helicopter; both will be equal”.

Student E5: “OK, so your statement is than a rebuttal!” [Pointing to student E8]

Student E7: “I think the claim should be: ‘The distance can be equal to displacement, but only if the movement is in a straight line’. Like when I walk in this straight line [she stands up and walks four steps in a straight line]!”

Student E6: “Okay, I agree. Then my original claim is not always true, but it can be the rebuttal!”

Group: “Yes! It is a strong argument!”

Nicol and Farlane-Dick’s (2006) self-regulated learning model contends that, the external feedback provided to students by their peers augment the students’ interpretation of the task and the path of learning: Peer- and Self-assessment. This was evident when Student E6 reconsidered his claim: that the two physical quantities cannot be equal, after Student E8 challenged it with a counter-claim. Student E7 produced a stronger claim with a qualifier, which the group accepted unanimously. Furthermore, the students in the group showed that they were competent with the TAP-protocol, identifying the different elements of TAP. The students were acting as instructional resources to each other, reaching consensus on the conception of distance and displacement (Wiliam & Thompson, 2007). Figure 4.4 illustrates these elements, namely: a claim, a warrant, a backing, a rebuttal and data for the claim. This is also an example of cognitive harmonization, characterized by agreement and collective consensus.

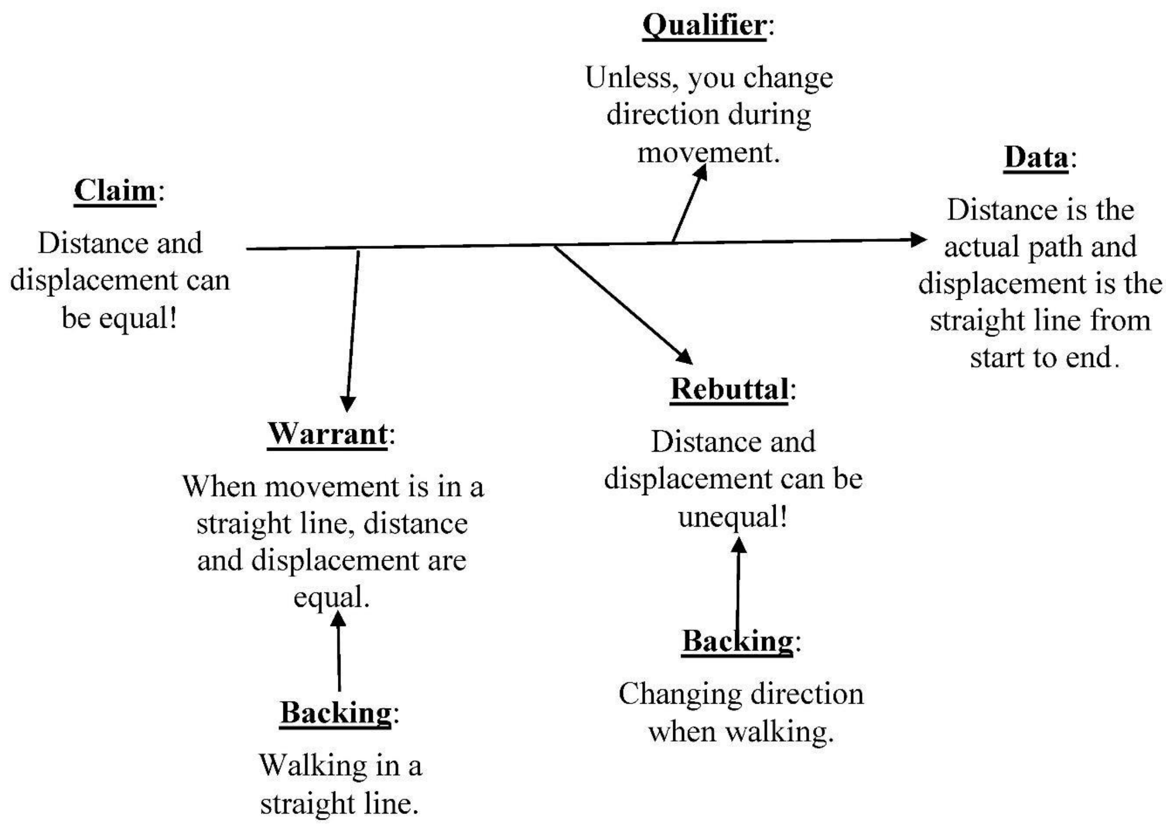

Figure 4.4: E-group's discussion in terms of TAP

This dialogical argumentation process obtains a Level 3 (second-highest category) in terms of the TAP levels of argumentation, involving most of the elements of TAP-protocol. It is also in accord with Toulmin's assertion: "Scientific arguments involve no real conflict of interest, nor are there any permanent winners or losers as a result of their resolution" (1958, p. 345). During the reflection on the feedback of the different groups, the educator provided clarification to the other groups who still had misconceptions about distance and displacement - Educator-facilitation.

The following excerpt illustrates how the construction of knowledge took within the ZPD framework - cognitive dissonance and equilibrium - within an inter-argumentation learning space, employing self-assessment and peer assessment. In this group discussion the students calculated and determined the magnitude of two supports that keep a horizontal beam in equilibrium, carrying different concentrated loads (Appendix 11: Statics worksheet, Question 2.2).

Student E3: “How did you guys used the law of moments? I always get it wrong!”

Student E6 [Using a ruler to act as the horizontal beam]: “The 25 kg load pushes the beam downwards, so it will rotate clockwise; and it is 3 m away from the left support. It will give us a clockwise moment of 25 times [multiplies with] 3”.

Student E8: “No, my bro [brother]! We must first change the 25 kg to newtons; we are working with forces!”

Student E6: “Oh, yes! That’s right, but the distance between the 110 N and 320 N is not given. Joh! I think there is a mistake in this question”.

Student E10: “No, man! I think we need to subtract 4.5 m from the 7 m, which is given [written] below the horizontal beam. That will help to calculate the missing distance”.

Group [after completing the calculations]: “Yes! The upward forces are equal to the downward forces!”

The students traversed the Zone of Proximal Development (ZPD). In the discussion, the students acted as instructional resources - scaffolding each other to get to the solution. The necessary support to students from the knowledgeable others, peers and educator is fundamental in formative assessment activities. DAAFLIM strategies provide these scaffolds to also gauge and track the learning process in the classroom.

4.4.5 C-group observation and TIM

a) C-group classroom observation. In the control group, the teaching process was strict and predictable. In most of the lessons, the educator arranged the desks in rows; only when group discussions took place were desks arranged in clusters. During most of the sessions, the educator taught standing in front of the classroom. At the start of the lessons, the educator introduced the topic briefly and asked questions determining the prior knowledge of the students. Thereafter, the educator explains the content of the lesson making use of notes projected on the data-projector screen and writing on the blackboard. After the educator presentation, he hands out worksheets for students to complete. The educator also walked among the students, giving assistance to those he thought were struggling with the activities.

The following is a typical discussion that took place in one of the few group work sessions. The students called the educator to clarify a disagreement that arose among the students. They discussed the following question: *"When a heavy book and a pen are dropped from the same height above the ground, which of the two objects will hit the ground first? Explain your answer"* (Appendix 12: Energy worksheet, Question 1.2).

Student C12: "I think the book will reach the ground first! The book is heavier than the pen".

Students C18: "No, I don't think so; the pen will reach the floor first! The book is big and flat and will experience more air resistance!"

Student C14: "No, guys! They will both fall to the ground at the same time"

Student C16: "How is that possible C14? The book and the pen have different shapes and weights. I am really confused now"

[They call the educator who is walking nearby the group.]

Student C14: "Meneer, meneer [Sir, sir]! Please explain help us here!

Educator: [They explain their positions to the educator.] "Let me show you. Observe what is happening here". [He took a book and a pen from the table and dropped them from the same distance above the floor].

Student C12: "Okay, it looks like they both hit the floor at the same time, Sir!"

Student C16: "Yes, this is strange; they really reached the floor at the same time!"

Educator: "Well, now you must explain why it is the case"

Student C14: "I have seen an experiment like this on the TV once, with an iron ball and feather, where the both fall with the same speed in a vacuum room; they reached the ground at the same time. So, they fall with the same acceleration of gravity to the ground, because it [gravitational acceleration] is a constant."

Student C18: "Yes, I see they both hit the floor together. But I still think the air resistance play a small role."

Educator: "Yes C14, you are right. That is precisely what happens! I will explain this later to the whole class."

This group discussion does not reveal effective interrogation and a consensus conception of gravitational acceleration. It seems that the students as well as the educator rushed to the answer of the question. The students could have spent more time unpacking and understanding the question before calling on the educator. When the educator intervened, he should have allowed for more discussion and posed probing questions before showing the demonstration and confirming the answer. Student C14 produced a valid answer, with no reference to the educator's demonstration. It is also possible that student C14 rote-learned the definition of gravitational acceleration and probably do not have a conceptual understanding of it, because she uses speed and acceleration interchangeably in her explanation. Furthermore, the educator could have assessed and addressed the misconceptions of the rest of the group. The group members and the educator did not provide an effective scaffolding process to assist student C12 and student C18 to have a valid conception of gravitational acceleration. This was a missed opportunity for the educator to enhance the conceptual understanding of the group. At the end of each lesson, the educator projected the correct answers onto the data-projector screen or wrote it on the blackboard, allowing the students to assess their own responses. Thereafter, the educator highlighted and explained some of the concepts that he observed when walking among the groups.

The TIM style of lesson presentation was the norm at the selected TVET college campuses. The TVET College is in the post-school education sector, a transition from school to university, creating uncertainty in college educators about their educator status - schoolteacher or university lecturer. The majority TVET college educator opt for the latter. The lecture-style methodology, which is a major part of TIM, does have its advantages over heuristic strategies. For instance, it allows students to see the lesson as a structured unit. In addition, it enables the educator to stress important facts and to show the 'big picture' to the students. However, its major disadvantage is that students become passive and consequently they lose interest in the presentation (Amabile, 1996). The lecture-style teaching based on traditional, teacher-centred, 'talk-and-chalk' teaching methodology used by many TVET College educators believing that it is an effective method of teaching (De Vos and Bulluigi, 2011). The 'talk-and-chalk' methodology, also part of TIM, demands that students have a high level of concentration. However, students are not able to stay focused for long periods; they are bound to lose interest in the presentation, leading to focusing on something else and possible disruptive behaviour (Gipps, 1994). Although the C-group lecturer attempted to change the mostly one-way communication style in the classroom, making use of group discussions and asking a few questions, he still limited the interactions between the students, the learning content and discussions. This could result in a situation where the student is confronted with new ideas that cannot be fitted into his/ her existing conception, leading to an inability to cope adequately with the new information (Skoumios & Hatzinikita, 2009). Creative teaching involves combining existing and new knowledge to create new knowledge to obtain a useful result (Amabile, 1996).

b) Demonstrations of CAT, TAP and ZDP in TIM. The TIM activities in the C-group classroom also had some evidence of CAT, TAP and ZDP. The following sections illustrates episodes of how C-group students demonstrated the evidence or not of CAT, TAP and ZDP.

The following excerpts of the C-group students' discussion, mentioned earlier, illustrating the different categories of CAT (Appendix 12: Energy worksheet, Question 1.2):

- **Dominant mental stage** (when it is the most adaptable to a given context). Student C18: "No, I don't think so; the pen will reach the floor first! The book is big and flat and will experience more air resistance!"

- **Suppressed mental state (**when the dominant cognitive stage is overpowered by another more adaptable mental stage). Student C18: "Yes, I see they both hit the floor together. But I still think the air resistance play a small role".

- **Assimilated mental state** (when the dominant mental stage is absorbed into another more adaptable mental stage). Student C12: "Okay, it looks like they both hit the table at the same time, Sir!"

- **Emergent cognitive stage** (when an individual has no previous knowledge of a given phenomenon). Student C16: "Yes, this is strange; they really reached the floor at the same time!"

- **Equipollent mental state** (when two competing ideas or worldviews tend to co-exist in the mind of the individual, without necessarily resulting in a conflict). None is presented.

The C-group educator did not encourage maximum participation from the group and conveniently relied to the response of student C14 in the gravitational acceleration group discussion. Bricker and Bell (2008) assert that certain concepts of science are more difficult for students to understand than others, therefore, the educator should have made sure the students conceptualize it as: "gravitational acceleration is the constant rate of velocity at which an object falls" and "that the acceleration is independent of the mass of the object" (Clugston, Flemming & Vogt, 2002). Furthermore, the educator and group failed to address the misconception held by the students, that gravitational acceleration depends on the mass and shape of an object. The C-group students did not present any equipollent views.

The following group discussion between C-group students is analysed according to the TAP-protocol. The students were discussing how to calculate the components of a vector: "*A force of 50 N is at an angle of 30° with the horizontal plane. Calculate the magnitude of the horizontal and vertical components of the force*" (Appendix 11: Statics worksheet, Question 3.2).

Student C3: "We must first draw the 50N force in a right-angle triangle to find the other two sides".

Student C7: "Okay, then we use sin and cos to find the components of the force".

Student C19: [Using a calculator] "The vertical component is 25N and the horizontal component is 43,3N".

Student C5: "Yes, it is right! If we use the Pythagorean Theorem give the same answer".

[The rest of the group nod their heads in agreement.]

Figure 4.5 illustrates the different elements of TAP according to the group discussion.

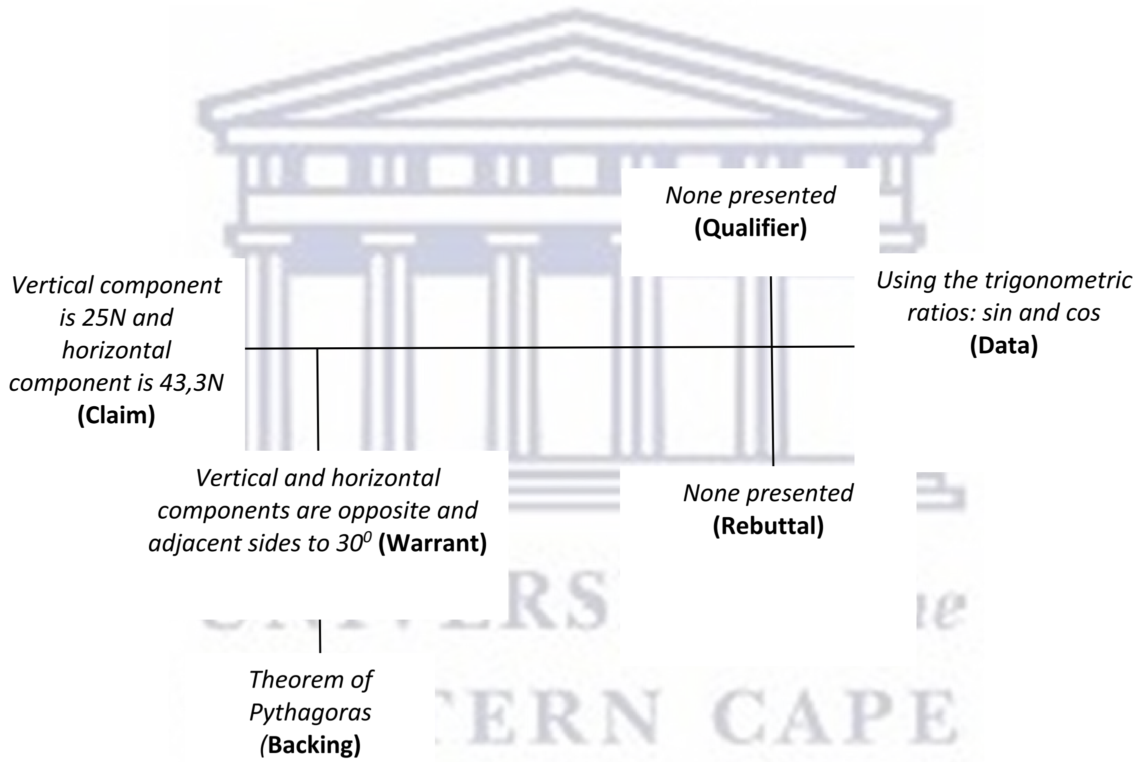

Figure 4.5: C-group's discussion in terms of TAP

This discussion process obtains a Level 2 in terms of the TAP levels of argumentation (Section 2.6), lacking a qualifier and rebuttal in terms of the TAP-protocol.

When analyzing the group discussions in terms of the ZPD framework some form scaffolding did take place. In the first group discussion C14 and the educator were the more knowledgeable other scaffolding the rest of the group; and in the second group discussion the students were scaffolding each other, serving as learning resources (Black & Wiliam, 2010).

4.4.6 Interpretive summary. The comparability of the two groups at the start of the study achieved approximately 25% average scores in the pre-test of the SAT. The t-test statistics also confirmed that there were no statistically significant differences between the groups at the start of the study. Furthermore, the results of the two groups in the pre-test suggested that the students had some conception of the selected topics. Noted that the experimental group scored the highest in Question 1 (SI-units) and the control group scored the highest in Question 4 (Energy). However, both groups achieved the lowest scores in Question 3 (Statics). This observation could be attributed to the fact that the students were exposed to the concepts of SI-units and Energy in previous courses and that Statistics was emergent to them.

The control group received the expository traditional instructional method (TIM) and the experimental group the DAAFLIM intervention pedagogy for ten weeks. The comparison of the pre-test and the post-test results revealed that both groups experienced a statistically significant difference in their SAT scores: the experimental group had a 17.4 (56%) difference and the control group 9.0 (29%) difference. This suggests that the experimental group experienced a greater conception of the selected topics than the control group. Therefore, one assumes that the DAAFLIM intervention strategy was more effective than the traditional instructional method received. Furthermore, the experimental group outperformed the control group in all the questions in the post-test of the SAT. The highest performance was in Question 4 (Energy) and the lowest performance in Question 2 (Dynamics) for both groups in the post-test. The question where the greatest conceptual change took place was Question 3 (Statics).

Both educators started by introducing the objectives of the lessons and determined the prior knowledge of the students. They also used group work activities, encouraging maximum participation in the class. The educators made use of technology in their lesson presentations - data projector and Plicker quiz-cards. There were also formative assessment strategies used in both classrooms at different stages of the lessons: question-and-answers, self-assessment, peer assessment and teacher-review. At the end of the lessons, both educators checked whether the objectives of the lessons were covered and achieved.

However, despite these similarities in the presentation and methodologies used in the two classrooms, distinct differences emerged. The experimental educator allowed the students to be more actively involved in the lessons, by creating different learning spaces – individual, peer, group and whole-class discussion spaces – where students felt free to ask questions at any time. The intra-argumentation (individual) learning space of DAAFLIM relates to Butler and Winne's (1995) assertion of self-regulated learning, "individual engagement with activities allows the students to draw on prior knowledge and personal motivational beliefs, assisting them to construct knowledge and a personal interpretation of the task and its requirements".

Although both educators used formative assessment strategies, the E-group educator applied DAAFLIM strategies intentionally and explicitly to gauge the progress of the students at various stages: question-and-answers in all learning spaces; Plicker card during nodal and reflective space; think-pair-and-share during group work space; peer assessment/ feedback; group assessment/ feedback and comment-marking. On the other hand, the control educator made use of formative assessment to get a general impression, whether the class as a whole understood what he explained. He mainly used question-and-answer at the introduction and conclusion of the lessons and self-assessment at the end of the group work sessions.

The verbal responses of the experimental group were also more elaborate and logical compared to the control group, providing backings and sometimes rebuttals for their responses in most cases. The authoritative approach used by the control group educator focused more on the scientific worldview of the activities, in contrast to the experimental educator who used the dialogical approach to explore and tried to relate to the students' personal ideas and their lived experiences. It is important that an educator acquire the necessary communicative repertoire to impart content knowledge effectively and to have a positive influence on the students' personal and cultural beliefs (Lehesvuori, Viiri & Rasku-Putten, 2010). The experimental educator possesses more of these skills in his communicative repertoire than the control educator did. Furthermore, the quantitative analysis of teacher-talk and learner-talk and student-centeredness of the class activities in Table 4.8 suggests that the experimental group experienced an interactive-dialogic communicative approach, implying that the DAAFLIM is student-centered. By contrast, the control group's results are indicative of a non-interactive, authoritative communicative approach, suggesting that the dominant lecture-style was educator-centered.

Table 4.8 reflects the results analyzed in terms of the communicative approaches model, suggesting that the control group experienced a non-interactive, authoritative communicative approach with a teacher-talk: learner-talk: silence ratio of 58:32:10. Furthermore, the results also indicate that a teacher-centred instructional atmosphere was present in the control classroom with a teacher-talk: learner-talk ratio of 64:36 (Appendix 13).

The responses of the focus group interviews also showed that students had a positive attitude towards the DAAFLIM compared to the expository traditional instruction (TIM). Typical responses in the experimental focus group were, "I could express myself freely and confidently in my group …" and "I liked it that we can ask questions anytime, and Sir don't go to the next topic if we do not understand the work; like the other lecturers" (Appendix 14). Therefore, lecturers must be competent in argumentation-instruction and formative assessment to become effective DAAFLIM practitioners in the classroom. In the constructivist classroom, the educator is a facilitator who plans, organizes, guides and provides directions to the student and scaffolds the construction of knowledge. The DAAFLIM framework includes the theoretical constructs of CAT, TAP and ZPD. DAAFLIM as a dialogical argumentation pedagogy are able to interrogate formal knowledge and informal knowledge concepts and considers the western science and traditional knowledge as complementary and equipollent. Toulmin's Argumentation Pattern (TAP) lends itself to deductive-inductive classroom discourses, focusing on scientifically valid arguments; the more rebuttals used, the better the quality of the argument (Erduran et al., 2004; Osborne et al., 2004; Simon, Erduran & Osborne, 2006). This approach is in line with DAAFLIM, requiring students to interrogate, assess and give feedback to each other and the educator - providing evidence that the students have mastered those targets or goals. ZPD acknowledges that the educator is not a transmitter of knowledge, but rather a facilitator of the learning process. The teaching practices in the DAAFLIM classroom require that the students must actively participate in the activities, become more involved in the learning process and take responsibility for their own learning. Therefore, the students are not absorbers of knowledge, but active participants in constructing their own meaning during DAAFLIM activities. DAAFLIM helps students to take control of their own learning and become self-regulated students, actively constructing their own knowledge through metacognition.

Learning theories advocate for students' prior knowledge to be prioritized in the process instruction (Ausubel, 1968). In this regard, both educators attempted to engage the students in making predictions about the purpose of the artefacts used for the lessons. The teaching and learning support materials used for both groups seemed appropriate as demonstrations. However, Campbell and Lubben (2000) have argued that amongst the various resources a student bring into the science classroom is his/her own socio-cultural background. While the presentations in the C-group were practical and relevant, they were more focused on the western science worldview with no culturally relevant examples. As Jegede (1997) and Tobin & Garnett (1988**)** has suggested, traditional teaching approaches usually lead students to adopt learning strategies for the memorization of facts. Although, many educators are aware of formative assessment activities they do not include it explicitly for various reasons such as not having appropriate resource materials and time to do so. However, an important point of note with regard to departure from prior knowledge to new learning content of a lesson is to close the conceptual gap, where students learn from each other and using ZPD.

TAP and CAT are in agreement with socio-cultural constructivism as espoused by Vygotsky (1978), emphasizing the role of the social environment in learning and cognitive development. In Vygotskian theory, a mediator assists thinking and action between the student and the environment with the purpose of developing the student's cognitive capacity.

4.5 Overall summary

As indicated at the beginning of this chapter, the data obtained from the study was analysed and presented quantitatively and qualitatively, as deemed appropriate. In addition, where feasible, the dataset was analysed in terms of the DAAFLIM. However, only data related to sections 4.4.1, 4.4.2 and 4.4.3 were experimentally manipulated in the study.

The lecturers determined the prior knowledge of the students at the start of each lesson. The majority of the students in this study initially held a dominant Western Science conception about the selected science concepts. When engaged with the lesson activities, some students shifted towards the Traditional Knowledge conception, especially in the experimental group. The students found it easier to make a conception shift when dealing with selected natural phenomena, than with the Nature of Science tenets in the NOSIKS-Q.

Furthermore, the analysis showed that the students in both the experimental and control groups were comparable and held inadequate conceptions of the selected science concepts at the beginning of the study, according to the pre-test results in the Science Achievement Test. The knowledge that they had could be due to the prior knowledge they had from the previous study level, which also dealt with the same concepts at a lower level of difficulty. The post-test data showed improvement in the achievement of both the groups, thus indicating an improved understanding of the selected science concepts. This improvement is assumed to be because of the teaching methods used: traditional expository instruction method and the DAAFLIM. The E-group student's exposure to the DAAFLIM probably caused the scores of the experimental group to be higher than that of the control group. In terms of TAP the experimental group's responses appear stronger because the supporting data to the claims, than was the case in the control group at the post-test. This could probably be attributed to the different formative assessment strategies employed in the DAAFLIM model.

The questions based on concepts of SI-units and Energy were answered well, and the questions about Dynamics and Statics seemed to be more challenging to both groups of students. One could assume that this observation is because SI-units and Energy were mainly theoretical (recall) knowledge content, whereas Dynamics and Statics required knowledge that is more analytic. It was also evident during the intervention sessions that the dialogical argumentation and formative assessment strategies of the DAAFLIM enhanced the experimental group's conceptions of science concepts better than was the case with the control group. Furthermore, it was found that the responses of the experimental group in the SAT were better substantiated than those of the control group are. This supports the assertion of Lemke (1990, p. 121) that "Learning science involves learning to talk the language of science and acting as a member of the community of that practice".

In the experimental group, the lecturer acted as a facilitator during the group discussions and provided directions to the students, but ensured they were accountable for their own learning. Students worked in groups and acted as knowledgeable others in assisting their peers who found it difficult to understand the work (Vygotsky, 1978, p. 86). The mediation process took place through the interrogation of questions and eliciting dialogical argumentation from the students. The lecturer also encouraged maximum participation using examples to explain concepts. These activities could also be regarded as scaffolding in terms of ZPD. The lecturer seems to be creative enough to engage his students in understanding the concepts.

This study also showed that the biographic factors of age, gender and race did not have any statistically significant influence on the performance of the students in the post-test of the SAT. However, age, gender and race have to be taken into account, because not all the students have similar backgrounds or identities. It is important to be aware of the biographical and socio-cultural background of students when planning and teaching students from diverse cultural settings.

In keeping within the space allowed for a doctoral thesis and to avoid repetition of issues, only the major issues emanating from the study will be addressed in the concluding chapter.

CHAPTER 5

CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides an overview of the main findings relating to the students' conceptions of selected natural phenomena, Nature of Science, and selected science topics before and after exposure to DAAFLIM and TIM respectively; and whether students' conceptions relate to their sociocultural variables such as: gender, age and cultural groups. It also examines the implications of the findings in terms of policy, instructional practices, curriculum development, teacher education and future research. It is after this that some recommendations are made. The chapter addresses the purpose of the study, responses to research questions, implications and recommendations for classroom practice, educator professional development and further research.

5.2 Purpose of the study

The primary focus of this study is to compare the Dialogical Argumentation and Assessment for Learning Instruction Model (DAAFLIM) with the traditional expository instruction methodology (TIM) used by most lecturers at the TVET college, where the study took place. Furthermore, the study sought to determine whether the DAAFLIM intervention would enhance teaching and learning of the following selected science concepts namely: SI-units, dynamics, statics and energy. This study points out the importance of the educator's awareness about the conceptions of students thus allowing teaching strategy changes if needed. The manner in which students perceive Western Science and Traditional Knowledge could influence their learning and conception. Therefore, educators have to be culturally sensitive to the students' backgrounds.

Research on formative assessment and dialogical argumentation at TVET colleges within the South African context is scanty. I trust that the findings of this study may contribute to this knowledge field, helping educators to modify their methods of instruction and improved quality of teaching and learning. The problem of too much lecturing and not enough dialogue, failure to encourage active independent learning may be resolved by using DAAFLIM as a pedagogical model.

It is imperative to be conscious of the context and background of students, therefore, the study also focused on the effect biographic factors have on the conception of the selected science concepts when exposed to DAAFLIM. These among others include age, race and gender of the students, which might influence their motivation for learning, learning styles, and views about assessment. There exists a general assumption that all students in a classroom have the same socio-economic and educational background, and learn in the same way (Atwater, 1994). Therefore, teaching methodologies should consider the biographic background of different students. For instance, students with different ethnic backgrounds will most probably have different worldviews, therefore, DAAFLIM strategies like, think-pair-share, group discussions, peer-assessment and focus group interviews allow opportunities to exchange and appreciate diverse views.

5.3 Limitations

Limitations of any particular study concern potential weaknesses that are usually out of the researcher's control (Theofanidis & Fountouki, 2019). This study acknowledges the following limitations.

Lecturers and students have preconceived ideas and perceptions of teaching and assessment. This limitation should not undermine the positive perceptions of students and lecturers about alternative assessment strategies and willingness to use in the science classroom. Context-based paper-and-pencil test items require students to have sufficient reading ability to analyze and understand the scenarios before they can respond. The fact that English is a second language for most of the participants could have contributed to problems of interpretation and understanding of the tasks, as well as poorly expressed responses from the students. The study minimized language problems of interpreting questions by making use of pictures and symbols to represent contexts and to avoid lengthy descriptions, and by including local labels for some concepts. Some short-answer questions were also used to this end.

Exposure to enquiry-based teaching and formative assessment activities before this study, might have influenced the participation of the E-group and C-group students. However, the E-group's encounters with the DAAFLIM may have been limited, although three months of induction in the protocol and practice of the DAAFLIM were included as a means of promoting familiarity. Hord (1987) noted that investigations like this study is not an event but a process that often needs a long time to take effect. Hord further warns of the possible and permissible change affect, stating that the participants' behaviour due to demands and pressure produces results from innovations only to a limited extent. There is sometimes a danger of innovations rejected due to premature conclusions.

The huge teaching workloads of lecturers and few administration periods at the TVET College make it difficult to spend enough time to prepare and plan for effective student engagement. However, both the control and experimental lecturer committed to providing the required support for this study. The behaviour of students in the classrooms varied greatly, from being inquisitive and eager to learn, to delinquent, apathetic and disruptive behaviour. This made it difficult to conduct lesson activities according to the planning and preparations, as a great amount of time are wasted to discipline students.

5.4 Summary of results

The conceptions that students and educators hold affect the motivational levels they may have, as well as the effort they may invest in learning and teaching (Kelly, 2007). The awareness of the conception that students hold may be important for educators in the construction of tasks and the use of these tasks in classrooms. This case study involved a targeted sample of college students, and its findings are specific. It provided some useful indicators about the applicability and effectiveness of DAAFLIM as an instructional model. These indicators are lively discussions, confident arguers, student-centeredness, high level of student-talk, etc. which translated into enhanced performance, as illustrated by the experimental group. The findings are applicable to situations beyond the parameters of this case studied. The primary objective of the study was to establish whether the DAAFLIM intervention was effective in enhancing the conception of the selected science concepts. The findings of this study also shows that teaching, learning and assessment do not take place in isolation and considered the contextual factors. For instance, always show students the outcome or product before they do it and presenting a criterion-referenced rubric together with the task. The study also investigated conceptions held by students, of the selected science concepts, before and after the study, in order to identify cognitive shifts if any. Biographical aspects such as age, gender and the cultural group of the students were also compared to the performance scores in the Science Achievement Test (SAT), in order to see if the DAAFLIM intervention pedagogy may have influenced the outcome.

5.4.1 Research Question 1: Students' conceptions of natural phenomena and Nature of Science. The findings of the NOSIKS-Questionnaire responses indicate that the majority of students in both the E-group and C-group appear to hold an overall dominant Western Science conception regarding the selected natural phenomena and Nature of Science tenets. The E-group seems to express more equipollent responses in the post-test than the C-group, suggesting that they are able to express a concept confidently in a western science and/ or indigenous knowledge worldview. The frequency of scientific and elaborate arguments in the responses of the experimental group were higher than the control group. These differences might be attributable to the DAAFLIM experience of the E-group, making them aware of the relevance of Traditional Knowledge and the Western Science concepts. The ability to use argumentation during the DAAFLIM lesson activities could have enhanced students' awareness and understanding of science concepts within the traditional knowledge and the nature of science context. DAAFLIM allowed for dialectic exchanging of ideas and opinions to bridge the Traditional Knowledge to the Western Science worldview, and vice-versa, in a way that both thought systems maintain their integrity (Ogunniyi, 2005). The dominant Western Science responses could be attributed to the fact that the South African curriculum is still mostly based on western values emphasizing individualism, competitiveness, dualistic thinking and a belief in control over nature.

5.4.2 Research Question 2: Students' biographics and DAAMFLIM. Social influences play a very important role in how students learn (Vygotsky, 1978; Bandura, 1986). Therefore, it is crucial that educators are aware and responsive to the sociocultural backgrounds of their students – not using a 'one size fit all' approach. Kesamang & Taiwo, (2002) found that students' socio-cultural background variables such as ethnicity and home environment have a significant influence on their achievement in school science learning. This study did not produce statistically significant differences to support Kesamang and Taiwo's findings when comparing the E-group students' biographical background to their performance scores in the Science Achievement Test (SAT).

Although no statistically significant difference was found for the selected biographical factors, the following differences were determined: female students performed better than the males; the older students outperformed their younger counterparts; and the Black students performed better than the Coloured students did.

5.4.3 Research Question 3: The TIM and DAAFLIM intervention. At the initial stage of the study, the comparability of the E-group and C-group groups were established in the pre-test of the Science Achievement Test (SAT). The pre-post test scores of the SAT indicated that both the E-group and the C-group enhanced their conceptions significantly which could be attributed to their interventions, DAAFLIM and TIM respectively. However, the E-group outperformed the C-group statistically significantly, in the post-test of the SAT; therefore, DAAFLIM probably was a more effective intervention compared to TIM. This finding is collaborated by the research of Black and William (2010) concluded that, "… formative assessment increases performance standards and improves overall student success". Furthermore, the DAAFLIM activities, including the group work and educator responsiveness, assisted the students to move from their actual development level to their potential development level through the zone of proximal development (ZPD) as espoused by Vygotsky (1978).

Although both the instructional methods of the E-group and C-groups were similar in some respects regarding formative assessment strategies: question-and-answer, group work and educator feedback; the DAAFLIM strategies: pre-post quiz, KWL-sheet, think-pair-share, comment marking were more prominent and the educator was more responsive. The results of Flanders' interaction analysis categories (Flanders, 1970) also show that the intervention received by the E-group was more student-centered compared to the intervention of the C-group.

The application of a various formative practices without an appropriate theoretical basis may not be effective in the classroom and produce the desired outcomes. This study found that the major features of the theoretical constructs CAT, TAP and social constructivism are adaptable with the five broad key aspects of DAAFLIM namely: explaining the aims and objectives, effective classroom discussions, constructive feedback, activating students as instructional resources and activating students to take ownership of their learning.

- TAP promoted the scientific discourses during the DAAFLIM activities creating more inductive-deductive logical reasoning during the group discussions and written responses compared to the interaction of the C-group. The TAP model is very useful for the responsive educator to analyze the argumentation discourse and to determine the quality of an argument in order to gauge and to capitalize on moments of synchronous contingencies.

- The students in this study come from diverse socio-cultural backgrounds. CAT assisted the educators to become aware of the student's worldviews before the study. The E-educator recognized the worldviews of the students and was responsive to the lived experience of students, non-logical experiences and beliefs.

- The students and educators acted as scaffolds using DAAFLIM strategies, traversing the students through the zone of proximal development (ZDP).

5.5 Implications

The findings of this study have important implications for curriculum development, educator professional development and teaching and learning in the science classroom.

5.5.1 Implications for policy and curriculum development. The Department of Higher Education and Training (DHET) develops the nationally TVET curriculum, giving guidelines on what must be taught, as well as how the prescribed course material must be presented to students. TVET colleges, being part of the post-school system, must contribute to the lives of individuals, the national economy and the development of an equitable and capable South African society (South Africa, Education Department, 2012). The DHET pronounces in the internal continuous assessment (ICASS) guidelines of the TVET syllabus that formative assessment tasks should not be seen as “separate from learning activities taking place in the classroom, but should serve as building blocks to summative assessment” (South Africa, Department of Higher Education and Training, 2019, p. 6).

DAAFLIM as an intervention strategy could assist the DHET to achieve this mandate. The curriculum planners should explicitly emphasize and give more priority to formative assessment aspects in the guidelines of the curriculum, prescribed methodologies, resources and the coordination of the provision of post-school education. Curriculum planners, college management and subject advisors should make DAAFLIM part of the educator training, course material and student resource material.

5.5.2 Implications for educator development. The findings of this study show that DAAFLIM: (1) enhanced the conception of science students on the selected science topics; (2) is a more effective instructional methodology in generating classroom enquiry-based discourse and student-centred teaching compared to the traditional instructional methodology; and (3) it could increase educators’ awareness of the students’ socio-cultural identity and values. These findings certainly have implications for educator training programs. The DHET supports the fact that pre-service and in-service educators be exposed to alternative and new instructional practices like DAAFLIM (South Africa, Department of Higher Education and Training, 2013).

There is a disjuncture between the theory taught in educator training programs and classroom practices (Schul & LeFebvre, 2015). I observed that, although most the formative assessment strategies advocated by DAAFLIM are included in educator training programs, many educators revert to the traditional instructional methodology, talk-and-chalk approach when faced with unexpected classroom management challenges. They claim that there is not enough time and space in the syllabus to maneuver (De Vos, 2011). The subject advisors and educator trainers must consider the following to ameliorate this anomaly:

- Develop dedicated lesson plans, resource material and classroom activities aligned to the course syllabus that includes DAAFLIM strategies.
- Provide opportunity for educators to become sufficiently trained in the use of argumentation instructional and assessment for learning skills.
- Expose educators to a large variety of DAAFLIM strategies and teaching techniques, that is already been implemented.
- Create "teacher learning communities" that meet on a regular basis to share best practices of DAAFLIM strategies.

5.5.3. Implications for teaching and learning. Educators are able to design lesson plans according to their pedagogical approaches in line with the subject guidelines (South Africa, Department of Higher Education and Training, 2013). Therefore, they have to consider the diversity and individuality of students in the classroom, avoiding a 'one-size-fit-all' approach. The important features of DAAFLIM are that it assists students to construct their own knowledge, allow the educator and students to gauge their progress, promotes dialogue among/ and between students and the educator.

Formative assessment is discovering what students know while they are still in the process of learning, which is very challenging. Therefore, designing the right instructional method can feel high stakes for educators, not students, because the educator must determine what to teach next, are the students ready to move on or who need to follow a different pathway? In order to determine what students really know, educators have to consider alternative interactive teaching styles. A single source of data, no matter how well designed, is not enough information to help plan the next step in instruction (Armstrong & Thornton, 2012). Furthermore, different learning tasks are best measured in different ways; therefore, educators need a variety of formative assessment tools that to deployed quickly, seamlessly, and in a low-stakes way — all while not creating an unmanageable workload. Formative assessments generally just need to be checked, not graded, to get a basic understanding on the progress of individual students, or the class as a whole. Therefore, the following formative assessment strategies, which is part of the DAAFLIM methodology, is very useful in the teaching and learning process (Jaques, 2003):

- Entry and exit slips/ cards: Those marginal minutes at the beginning and end of lesson can provide great opportunities to find out what students know.
- Polls and quizzes: To find out whether the students really know as much as you think they know.
- Focused observation form: Keeping track and taking quick notes on a tablet or smartphone while students work can provide valuable data.
- Think-pair-share/ TAG feedback: Peer-feedback process where students share the feedback they have for a peer; you gain insight into both students' learning.
- Five-minute focused interview: A discussion-based assessment method, digging deeper into students' understanding of content.
- Asynchronous feedback: For more introverted students, out-of-class assessments and anonymous feedback students could use digital software: Flipgrid, Explain Everything, or Seesaw to record their answers, to prompts and demonstrate what they can do.
- Sticky notes: Get a quick insight into what areas students think they need assistance by writing areas in separate columns on a whiteboard. Students answer on a sticky note and then put the note in the correct column — you can see the results at a glance.

No matter which tools the educator select, he must ensure that it is only assessing the content and not getting lost in the assessment logistics – it must be fit for purpose.

5.6 Recommendations

The findings of this case study conducted at two campuses of a TVET College, are particular to the study sample; even though some of its findings may be similar to results from other studies (Black & Wiliam, 2009). The following recommendations are proffered.

5.6.1 Recommendations for teaching and learning.

This study opens up spaces for students' input and for the voices of students to be 'heard' in matters concerning the teaching and learning process. In order to promote and develop higher order thinking and problem-solving skills we must use instruction and assessment, which directly reflects these processes. This study also promotes problem-based teaching which focuses on authentic problems and place-based issues. Therefore, there should be a greater emphasis on pre- and in-service professional development and skilling educators for this type of teaching.

In administering the DAAFLIM activities, problems emerged due to the design of the tasks and worksheets. The educator waste time in handing out the worksheets and sometime students, have to complete more than one worksheet. The collection of the worksheets afterwards and giving feedback were also problematic. Therefore, it is recommended to choose and design formative assessment tasks, worksheets and activities, which do not require additional assistance for students to complete and to review. This challenge could be address by using a blended learning approach, combining formative assessment tasks with digital resources like cell phones and computers, and appropriate software e.g.: Plickers, Flipgrid, Kahoot, Quizlet, Animoto, Peardeck, MarcoPolo, etc.

5.6.2 Recommendations for further research. The awareness of the educator's worldview and attitudes towards the students' conception, cultural background is very important in the interaction between the educator and the student, because the fact that the educators themselves are also products of their cultural backgrounds, which could influence their instructional approach. What effects will students' worldviews and attitudes have on the teaching and learning environment? How will these effects influence students' conception of scientific concepts? According to the Department of Education, several times a week students cross from the culture of home, over the border, into the culture of science (in the classroom), and then back again (South Africa, Department of Education, 2012). Therefore, research is needed to establish whether the educators also practice border crossing between the worldviews as they teach, especially within the diverse cultural text of South African classrooms (Fakudze, 2004).

Secondly, this study has revealed that teaching and modeling instructional approaches in terms of DAAFLIM improved students' conception of the selected concepts. However, the potential of the instructional approaches adopted in this study are worthy of closer consideration in future research using larger samples and involving longer duration to provide a more holistic analysis of the impact of DAAFLIM on the teaching and learning process.

Thirdly, the present study involved educators and students from an urban TVET College in the Western Cape Province, which differs greatly from rural TVET Colleges in terms of socio-economic conditions. Thus, the research at rural TVET Colleges in South Africa may give insights on how educators would implement the DAAFLIM in science classrooms, within their context.

5.7 Conclusion

In the main, the results from the study indicate that educators have to be aware, or at least have some sense, of the conceptions that students hold when entering the classroom. Being aware and knowledgeable when a particular worldview is appropriate to use, would be beneficial to the teaching and learning process. Furthermore, this study also emphasized the interrelatedness between teaching, learning and assessment as presented by the DAAFLIM strategies. The expository traditional teaching methodology (TIM) lacks emphasis on assessment for learning and responsive teaching during the instruction process, and assessment remains reserved for the conclusion of a content-based series of topics.

Summative assessment and formative assessment could be seen as the extremes the assessment continuum (Gipps, 1994). It is clear that not all evidence generated to serve a formative function serve a summative function. As Wiliam and Back (2010) assert that, "It would be very difficult to argue that responses to an 'off-the-cuff' question to a class in the middle of an episode of teaching would have any significance beyond the immediate context of the classroom". Conversely, evidence elicited at the end of a sequence of teaching can have very little formative influence on the students assessed (Rosenshine, 2012). However, between these clear cases, it seems that there may be some common ground between the formative and summative functions. Finding this common ground will be difficult, since the issues are subtle and complex and although both types of assessments have their crucial roles in education, formative assessment needs more prominence. This study contributes to the debate by advocating that formative assessment should be an integral part during instruction in the science classroom.

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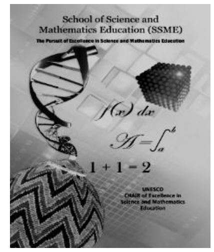

UNIVERSITY OF THE WESTERN CAPE

FACULTY OF EDUCATION

SCHOOL OF SCIENCE AND MATHEMATICS EDUCATION

APPENDIX 1 - LETTER TO DHET FOR ETHICAL CLEARANCE

13 April 2017

Department of Higher Education and Training (DHET)

103 Plein Street

Parliament Towers

Cape Town, 8001

Dear Sir/Madam

RE: APPLICATION FOR ETHICAL CLEARANCE

I hereby apply for ethical clearance to conduct educational research in one of the TVET Colleges on the topic:

Using Dialogical Argumentation and Assessment for Learning Instructional Model (DAAFLIM) to enhance science students' conception of selected science topics at a college

The details of the project are reflected in the attached research proposal and application form.

Sincerely yours

F George

UNIVERSITY OF THE WESTERN CAPE

FACULTY OF EDUCATION

SCHOOL OF SCIENCE AND MATHEMATICS EDUCATION

APPENDIX 2 - LETTER TO DHET TO CONDUCT RESEARCH

11 May 2017

Department of Higher Education and Training (DHET)
103 Plein Street
Parliament Towers
Cape Town, 8001

Dear Sir/Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH A TVET COLLEGE

I hereby wish to request permission to conduct a research study for my PhD thesis at a TVET College, in N2 classes as a data gathering exercise for my thesis.

I am a registered student at the University of the Western Cape (UWC). The title of my thesis: **Using Dialogical Argumentation and Assessment for Learning Instructional Model (DAAFLIM) to enhance science students' conception of selected science topics at a college**

This project will be conducted under the supervision of Dr. Cynthia Fakudze (UWC, Cape Town).

Attached is a copy of my thesis proposal. Upon completion of the study, I undertake to provide the Department of Higher Education and Training with a bound copy of the full research report. If you require any further information, please do not hesitate to contact me on 074 484 6099 or email me at frik.george@yahoo.com.

Thank you for your time and consideration in this matter.

Yours sincerely,

Frikkie George (Student number: 9073861)
University of the Western Cape (UWC)
Phone: 074 484 6099

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FACULTY OF EDUCATION

SCHOOL OF SCIENCE AND MATHEMATICS EDUCATION

APPENDIX 3 - LETTER TO NORTHLINK COLLEGE COUNCIL

11 May 2017

The Chief Executive Officer

Northlink College, Bellville

Dear Sir

RE: FIELD WORK FOR PHD STUDY IN EDUCATION

I herewith wish to apply for permission to perform a research study at Northlink College. I have chosen Northlink Belhar Campus because of its relevance to my research project.

I am a PhD student at the University of the Western Cape. The research study will include fieldwork and teaching observation in N2 Engineering Studies classes. All information gathered shall only be used for research purposes. The name of the College and the students involved shall not be disclosed to anyone.

At the end of my data analysis, I will give a summary report of my findings to the College. For ethical consideration in data gathering, the stamp of the College and signature will suffice for the purposes of proof of consultation and permission by college management.

Best wishes.

Frikkie George (Researcher)

Phone: 074 484 6099

UNIVERSITY OF THE WESTERN CAPE

FACULTY OF EDUCATION

SCHOOL OF SCIENCE AND MATHEMATICS EDUCATION

APPENDIX 4 - LETTER TO CAMPUS MANAGEMENT

13 April 2017

The Campus Manager

Northlink College campus (Belhar & Bellville)

Dear Sir

RE: FIELD WORK FOR PHD STUDY IN EDUCATION

I herewith wish to apply for permission to perform a research study at Northlink Belhar Campus. I am a PhD student at the University of the Western Cape. The research study will include fieldwork and teaching observation in N2 Engineering Studies classes. All information gathered shall only be used for research purposes. The name of the Campus and the students involved shall not be disclosed to anyone.

At the end of my data analysis, I will give a summary report of my findings to the Campus. For ethical consideration in data gathering, the stamp of the Campus and signature will suffice for the purposes of proof of consultation and permission by campus management.

Best wishes.

Frikkie George (Researcher)

Phone: 074 484 6099

UNIVERSITY OF THE WESTERN CAPE

FACULTY OF EDUCATION

SCHOOL OF SCIENCE AND MATHEMATICS EDUCATION

APPENDIX 5 – LETTER OF CONSENT (STUDENT)

Date: __________________________

Dear Student

I would like to inform you that I was granted permission by the Department of Higher Education and Training (DHET) to conduct a research project at Northlink College from the ___________________ 2017 to ______________________ 2017. I am currently busy with my PhD degree in Education at the University of the Western Cape.

The purpose of the research is to determine the possible effect of dialogical argumentation and assessment for learning instructional model (DAAFLIM) to enhance N2-student's conception of selected science topics at a TVET college. Your participation will help to improve the teaching and learning of Engineering Science. You will not be negatively affected in any way during the study.

In order to do the investigation, your consent is required to participate in the research. The research will take place during normal college hours and you will be observed while engaging in dialogue and hands-on activities. You will also be asked to complete a questionnaire based on your prior knowledge and the knowledge you gained during your engagement with the hands-on activities and dialogical argumentation instructional model.

Please complete the slip below and indicate whether you will take part in this research study.

Yours in Education.

F George, Phone: 074 484 6099

✂........................✂...................... Cut off and return ....✂.......………✂

Permission slip: Indicate by making a tick (√) in the appropriate box.

☐ **Yes, I will participate in the research study.** ☐ **No, I do not want to participate.**

Name & Surname: ……… Signature: ……………   Date: __________2017

UNIVERSITY OF THE WESTERN CAPE

FACULTY OF EDUCATION

SCHOOL OF SCIENCE AND MATHEMATICS EDUCATION

APPENDIX 6 – LETTER OF INFORMATION REGARDING RESEARCH

Dear Sir/Madam

I am a registered PhD student at UWC and will be doing my research in N2 Engineering Studies classes. The title of my study: **Using Dialogical Argumentation and Assessment for Learning Instructional Model (DAAFLIM) to enhance science students' conception of selected science topics at a college**

Three N2 classes will be used to conduct the research, of which two class groups at Campus 1 and one class group at Campus 2. The gathering of data will take place during the second trimester, 22thMay 2017 to 11thAugust 2017.The researcher will teach the Experimental class group and Control class group 1 at Campus 1 and another lecturer will teach the Control class group 2at Campus 2. The students will complete a questionnaire and an achievement test. Focus group interviews will be conducted with some of the participating students.

Students will be requested to complete consent forms in order to participate in the study. The research will take place during normal college hours, which will involve observation of lessons while students are engaging in dialogue and hands-on activities. Students will also be asked to complete a questionnaire based on their prior knowledge and the knowledge they gained during their engagement, the hands-on activities and dialogical argumentation instructional model. The students will not be negatively affected in any way and the anonymity of all participants will be guaranteed.

Feel free to contact my supervisor Dr. Cynthia Fakudze at 021 959 3687or myself at 074 484 6099.

Best wishes.

Frikkie George

Phone: 074 484 6099

APPENDIX 7 – UWC CLEARANCE CERTIFICATE

UNIVERSITY of the WESTERN CAPE

OFFICE OF THE DIRECTOR: RESEARCH
RESEARCH AND INNOVATION DIVISION

Private Bag X17, Bellville 7535
South Africa
T: +27 21 959 2988/2948
F: +27 21 959 3170
E: research-ethics@uwc.ac.za
www.uwc.ac.za

13 June 2017

Mr F George
Faculty of Education

Ethics Reference Number: HS17/4/17

Project Title: Using dialogical argumentation and assessment for learning instructional model (DAAFLIM) to enhance N2-students conception of selected science topics at a TVET college

Approval Period: 06 June 2017 – 06 June 2018

I hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval. Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

PROVISIONAL REC NUMBER - 130416-049

APPENDIX 8 - Work Scheme of study

Engineering Science N2 Trimester 2

Week	Proposed Date T2	Content Coverage	Date Completed	Signature
Week 1	**22-26 May**	**Science Achievement Test (SAT): Pre-test**	Mon. 22/5	
		Module 1: SI-units & Dynamics		
		1.1 Scalars and Vectors	Tue. 23/5	
		1.2 Distance, Speed, Displacement, Time, Velocity, Mass & Weight	Wed. 24/5	
Week 2	**29-02 June**	1.3 Graphs of constant and accelerated motion	Mon. 29/5	
		1.4 Vertical Projection	Wed. 31/5	
Week 3	**05-09 June**	1.5 Derivation of equations of motion	Mon. 05/6	
		Module 2: Statics		
		2.1 Parallelogram of forces, resultant and equilibrant	Wed. 07/6	
Week 4	**12-16 June**	2.2 Triangle of Forces	Mon. 12/6	

		2.3 Scale Drawings	Wed. 14/6	
Week 5	**19-23 June**	2.4 Moment of Forces. Beams	Mon. 19/6	
		Module 3: Energy and Momentum		
		3.1 Energy and Conservation of Energy	Wed. 21/6	
Week 6	**26-30 June**	3.3 Momentum	Mon. 03/7	
		3.4 Momentum and Energy	Wed. 05/7	
Week 7	**03-07 July**	**Revision**	Wed. 05/7	
Week 8	**10-14 July**	**Science Achievement test: Post-test**	Wed. 12/7	

APPENDIX 9 – Science Achievement Test (SAT)

Engineering Science – N2

CODE: …………………………….   Class: …….   Date: …………….

SECTION A: Biographic detail (5 minutes)

1. Gender:	Male	Female		**2. Age (years):**	17 and younger	18 – 21	21 and older
3. Race:	Coloured	Black	White	Other:			
4. Which of the following do you have at home?	DStv	Internet	Own cell phone	Computer			
5. Home language:	Afr.	Eng.	Xhosa	Other:			
6. Religion	Christian	Moslem	Other:				

SECTION B: Achievement Test (Total: 31 marks)

Full mark: Half mark: √

QUESTION 1:

SI-units and conversions (time: 5 minutes, marks: 5)

1.1 Redraw and complete the following TABLE:

	QUANTITY	SI-UNIT (symbol)
Example	*Force*	*N*
1.1.1	Acceleration	m/s^2 √
1.1.2	Energy / Work done √	J

(1)

1.2 Convert the following (show calculations):

1.2.1 0,065 m to .... cm => **6,5 cm** (1)

1.2.2 120 km/h to m/s => **17,65 m/s** (1)

1.3 A girl has a mass of 45 kg when she weighs her on a bathroom scale on Earth ($g = 9,8 m/s^2$).

1.3.1 Calculate the weight of the girl.

W = m.g = (45).(9,8) = 441 N (1)

1.3.2 Will the weight of the girl be **THE SAME, LESS** or **GREATER** on the Moon? Explain your answer.

Less, the force of gravity on the Moon is less. (1)

[5]

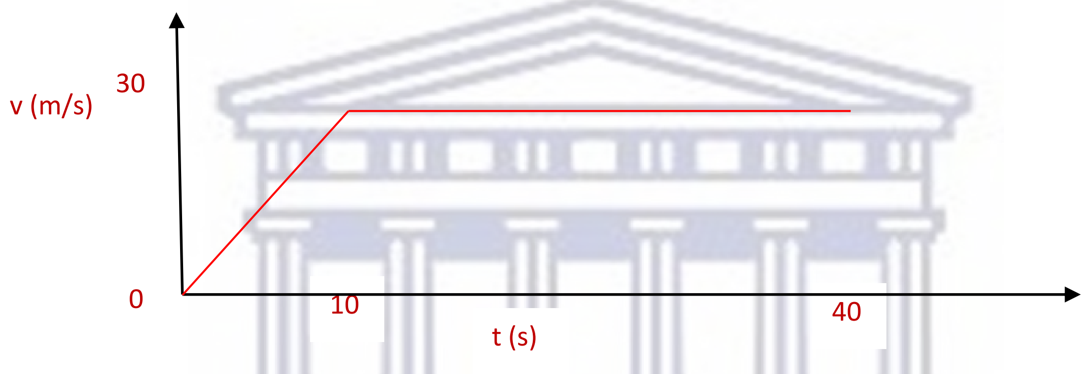
QUESTION 2:

Dynamics (time: 10 minutes, marks: 10)

2. A stationary taxi starts from one stop and accelerates uniformly on a straight road. The **TABLE** below indicates the data of the motion of the taxi.

Velocity (m/s)	0	30	30	30
Time (s)	0	10	30	40

2.1 Make use of the data in the table and draw a velocity-time graph for this motion.



(3)

2.2 Make use of the graph and calculate the following:

2.2.1 The acceleration of the taxi.

$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{30-0}{10-0} = 3m/s^2$$

(2)

2.2.2 The total displacement of the taxi for the 40 seconds

S_{tot} = ½ (10)(30) + (30)(30) = 1050 m

(2)

2.2.3 The average velocity of the taxi during the 40 seconds.

$$v_{ave} = \frac{S_{tot}}{t_{tot}} = \frac{1050}{40} = 26,25\ m/s$$

(2)

2.3 Explain what the difference between distance and displacement is.

Distance is the actual path followed; and displacement is the straight line from the starting point to end.

(1)

[10]

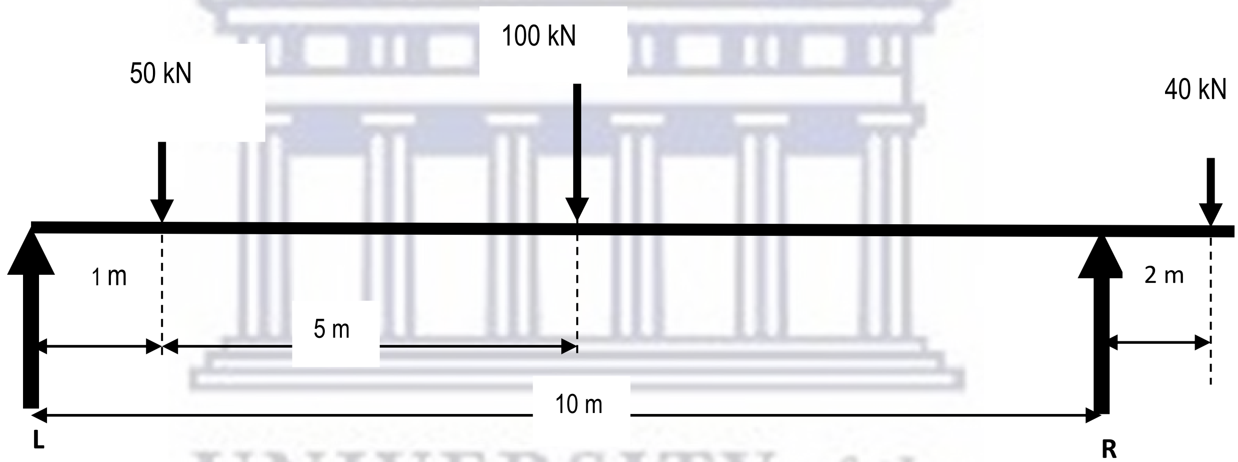
QUESTION 3:

Statics (time: 10 minutes, marks: 9)

3.1 If you are sitting on a chair, is the chair exerting any force? Explain your answer.

Yes, the reaction force pushes you up with the same force as your weight. (1)

3.2 Study the horizontal beam with three concentrated loads acting on it, supported by two reaction forces**, L** and **R**, as shown below.



3.2.1 Calculate the reaction force at R by taking the moments about reaction L.

Moments about reaction force L:

Σ Clockwise moments = Σ Anti-Clockwise moments

(50 x 1) + (100 x 6) + (40 x 12) = R x 10

R = 113 kN (3)

3.2.2. Calculate the reaction at L by taking the moments about reaction R.

Moments about reaction force R:

Σ Clockwise moments = Σ Anti-Clockwise moments

(40 x 2) + (L x 10) = (100 x 4) + (50 x 9)

L = 77 kN (3)

3.2.3. Proof that the beam is in equilibrium (Newton's 3rd Law).

Σ Upward forces = Σ Downward forces

77 + 113 = 40 + 100 + 50

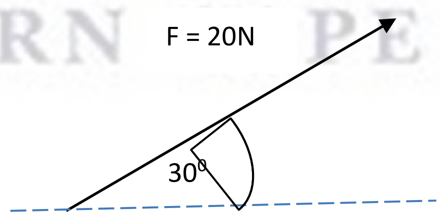
190 kN= 190 kN (1)

3.3 A 20 N force is pulling 30^0 above the right horizontal. Determine the vertical component of the 20 N force.

VC = $F\sin 30^0$

= $(20)\sin 30^0$

= 10 N



(1)

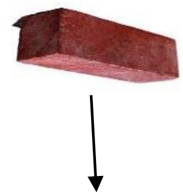
[9]

QUESTION 4:

Energy (time: 10 minutes, marks: 7)

A brick with a mass of 2 kg is released from a building at a height of 15 m above the ground. Calculate:

4.1 The potential energy of the brick just before being released.



PE = m.g.h = (2)(9,8)(15) = 294 J (1)

4.2 The velocity with which the brick strikes the ground.

$v^2 = u^2 + 2gS = 0 + 2(9,8)(15) = 294$ or $PE_{top} = KE_{bottom}$

v = 17,15 m/s $294 = ½(2)v^2$ (2)

4.3 Calculate the magnitude of the momentum of the stone when it strikes the ground.

p = m.v = (2)(17,15) = 34,29 kg.m/s (2)

4.4 Explain what the difference between potential energy and kinetic energy is.

Potential energy is due to position or strain and kinetic energy is due to motion. (1)

4.5 Is it possible to create or destroy energy? Explain your answer.

No, energy can only be transferred (Conservation of energy)/ Yes, metaphysical explanation. (1)

[7]

Grand total: 31

SECTION C: NOSIKS-Questionnaire (10 minute)

(i) Indigenous Knowledge items

Example - You wake up early in the morning and notice that there is dew on the grass. Your parents say that means there is lots of moisture in the air and there will be rain. What should you do? Plan a day of indoor activities or a day outdoors.

What is your view about the ideas expressed above?

a) **Scientific understanding:** *Dew on the grass means it will be a warm day, because the water evaporates from the cold grass into the warm air, forming droplets on the grass.*

Source: [Books] [Media] [**School**] [other]

b) **Personal understanding:** *Because in my cultural we say, "Dew on the grass, rain won't come to pass."*

Source: [Family] [Religion] [**Culture**]

Question 1 (Universe creation)

Many scientists believe that the universe occurred by chance (Big Bang), and since then has been undergoing continuous evolution. On the other hand, many people adhere to the religious or cultural view that a supernatural being is created and controls the workings of the universe.

Express your honest opinion on both worldviews:

a) **Scientific understanding:**

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………… **Source**: [Books] [Media] [School] [other]

b) Personal understanding:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………… **Source**: [Family] [Religion] [Culture]

Question 2 (Hysteria)

A girl suffering from severe hysteria (excessive or uncontrollable fear and anxiety) could not be cured by a medical doctor, but was cured within a week by a traditional healer.

What is your view, in terms of your…?

a) Scientific understanding:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………… **Source**: [Books] [Media] [School] [other]

b) Personal understanding:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………… **Source**: [Family] [Religion] [Culture]

Question 3 (Rainbow)

Scientists describe the occurrence of the rainbow because of the refractive dispersion ("bending") of sunlight shining through droplets. However, in many traditional cultures, the rainbow is believed to purport a good or evil event in the future.

What is your view, in terms of your …?

a) **Scientific understanding**:

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………… **Source**: [Books] [Media] [School] [other]

b) **Personal understanding**:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………….. **Source**: [Family] [Religion] [Culture]

Question 4 (Lightning)

Lightning is an electric discharge in the atmosphere. The very large and sudden flow of the charge that occurs in lightning has enough energy to kill people or do serious damage to buildings. In many traditional beliefs, witches can control lightning.

What are your views, in terms of your …?

a) **Scientific understanding**

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………..…… **Source**: [Books] [Media] [School] [other]

b) **Personal understanding**:

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………… **Source**: [Family] [Religion] [Culture]

(ii) NOS tenets

Example: "An auto mechanic must have an engineering science qualification to repair cars."

I agree with this statement: [YES] [NO]

Reasons: **I know of many good mechanics that do not have any qualifications, like my uncle and he is very successful**. **Source**: [**Family√**] [Religion] [Culture] [Books]

Question 5 - Science tells us the truth about the natural world.

I agree with this statement: [YES] [NO]

Reasons: ……………………………………………………………………………………………

…………………………………………… **Source**: [Family] [Religion] [Culture] [Books]

Question 6 - Scientific knowledge is trustworthy because it was proved in experiments.

I agree with this statement: [YES] [NO]

Reasons:

……………………………………………………………………………………………….

……………………………………… **Source**: [Family] [Religion] [Culture] [Books]

Question 7 - Scientific facts can be tested, and every test should give the same result.

I agree with this statement: YES NO

Reasons: …………………………………………………………………………………………

……………………………………… **Source**: [Family] [Religion] [Culture] [Books]

Question 8 - In their work, scientists are influenced by their socio-cultural (society) and psychological (mind) frameworks.

I agree with this statement: YES NO

Reasons: …………………………………………………………………………………………

……………………………………… **Source**: [Family] [Religion] [Culture] [Books]

Question 9 - The truth of science is the same for everybody. It does not depend on anyone's personal beliefs or situation.

I agree with this statement: YES NO

Reasons: ……………………………………………………………………………………

…………………………………… **Source**: [Family] [Religion] [Culture] [Books]

Question 10 - There is a step-by-step procedure for doing all scientific investigations.

I agree with this statement: YES NO

Reasons: ………………………..……………………………………………………………

…………………………………………… **Source**: [Family] [Religion] [Culture] [Book]

Question 11 - When the results of a demonstration experiment carried out by a lecturer are unexpected and do not confirm the theory, she/she should adjust them in order to confirm the theory.

I agree with this statement: YES NO

Reasons: ……………………………..……………………………………………………………

…………………………………………… **Source**: [Family] [Religion] [Culture] [Book]

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APPENDIX 10: DYNAMICS - Worksheet

Student name/ Group name: .... / Individual / Group / Class /

Intra-argumentation (Individual) | **Inter-argumentation (Group)**

1. Explain the meaning of the following terms and provide an example of each:

1.1 Vector quantity –

Has both magnitude and direction. Force, weight, …

1.2 Scalar quantity –

Has only magnitude. Mass, energy, …

1.3 Speed –

Rate of change of distance. Distance covered in no specific directions, within a specific period.

1.4 Velocity –

Rate of change of displacement. Displacement covered in a specific direction, within a specific period.

1.5 Is it possible that distance and displacement can have the same magnitude? Explain your answer.

Yes, if the object moves in a straight line.

1.6 Does the magnitude of the acceleration of a stone increase, decrease or remain the same when thrown vertically straight upwards? Explain.

It remains the same; it experiences gravitation acceleration, which is constant near the surface of the earth.

Met outcomes	Not Yet	Note that ...

2. Complete the following exercises. Show all the calculations:

Convert the following:

2.1 $360\ m/s \quad to \quad km/h$

1 296 km/h

2.2 48 cm to m

0,48 m

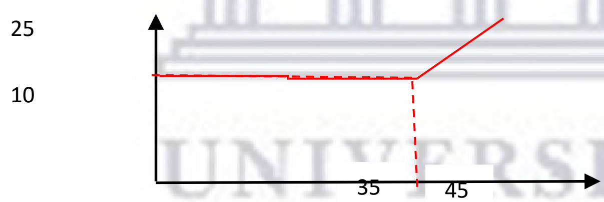
2.3 5,4 Gigajoule to Mega joule

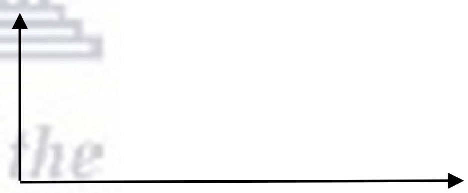
5 400 Mega joule

Met outcomes	Not Yet	Note that ...

3. A lorry is travelling at a constant velocity of 36 km/h for 35 seconds and then accelerates uniformly to a velocity of 25 m/s in 10 seconds. The lorry is moving on a straight road.

3.1 Draw the velocity-time graph for this motion





Using the graph, calculate:

3.2 The acceleration of the lorry.

u = 36 km/h = 10 m/s

$$a = \frac{25-10}{10-0} = 1.5 m/s^2$$

3.3 The velocity of the lorry after 40 seconds.

$$v_{40s} = 10 + (1.5)(5) = 17.5m/s$$

3.4 The total displacement that the taxi has undergone.

$$S_{tot} = (10)(45) + \frac{1}{2}(10)(15) = 525m$$

3.5 The average velocity of the taxi during the total time

$$v_{ave} = \frac{S_{tot}}{t_{tot}} = \frac{525}{45} = 11.67m/s$$

Met outcomes	Not Yet	Note that ...

4. A motorcycle starts from rest then accelerates at 4 m/s^2 until its velocity is 72 km/h. Determine the following:

4.1 The time taken to reach the velocity of 72 km/h

t = (72 km/h)/(4 m/s^2) = (259,2 m/s)/(4 m/s^2) = 64,8 seconds

4.2 The distance travelled during the time.

S = ut + ½at^2 = 0 + ½(4)(64,8)^2 = 9 466,88 m

4.3 A ball thrown vertically upwards, reaches maximum height and falls back to reach the original position after FIVE seconds. Determine the maximum height that the ball had reached.

$S = ut + ½at^2 = 0 + ½(9.8)(5÷2)^2 = 30,625$ m

Met	Not Yet	Note that ...

----o0o----

APPENDIX 11: STATICS - Worksheet

Student name/ Group name: .... / Individual / Group / Class /

Intra-argumentation (Individual)

Inter-argumentation (Group)

1. Explain the meaning of the following terms and provide an example of each.

1.1 Resultant force-

Single force that can replace a system of forces and still have the same effect as the system.

1.2 System of forces in equilibrium-

Two or more forces acting on the same point/ body.

1.3 Triangle law of forces-

When three forces act on an object and the object is in equilibrium, the tree forces can be represented as the sides of a triangle taken in order.

1.4 Torque-

It is the turning effect of a force about a point.

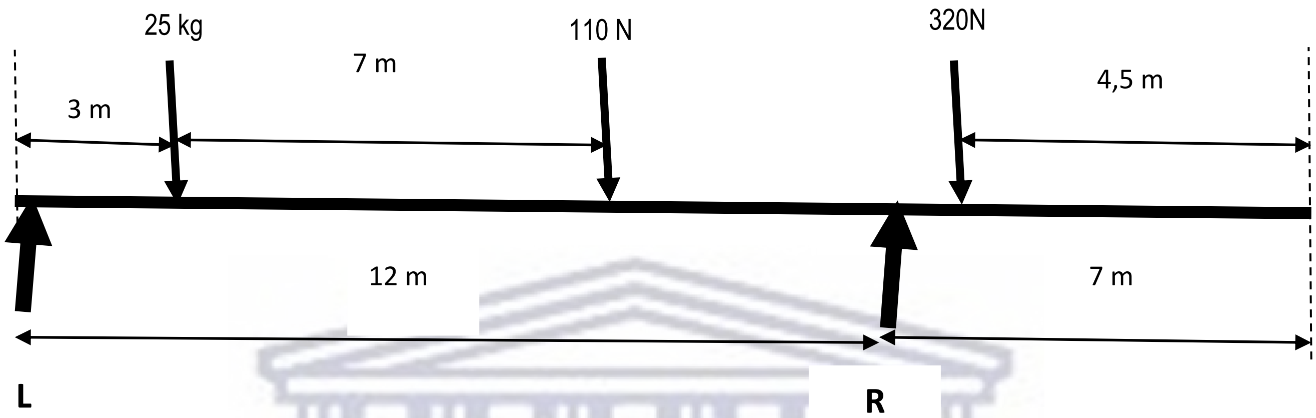
1.5 Law of moments-

A system of forces is in equilibrium when the sum of the clockwise moments about a point is equal to the sum of the anticlockwise moments about the same point.

Met outcomes	Not Yet	Note that ...

2. Complete the following exercises. Show all the calculations:

2.1. Study the following diagram and calculate the reaction at L and R by taking moments at both supports.



Moments about L:

Sum of clockwise moments (CWM) = Sum of anti-clockwise moments (ACWM)

(3 x 245) + (10 x 110) + (14,5 x 320) = 12 x R

R = 539,583 N

Moments about R:

CWMs = ACWMs

(2,5 x 320) + (12 x L) = (2 x 110) + (9 x 245)

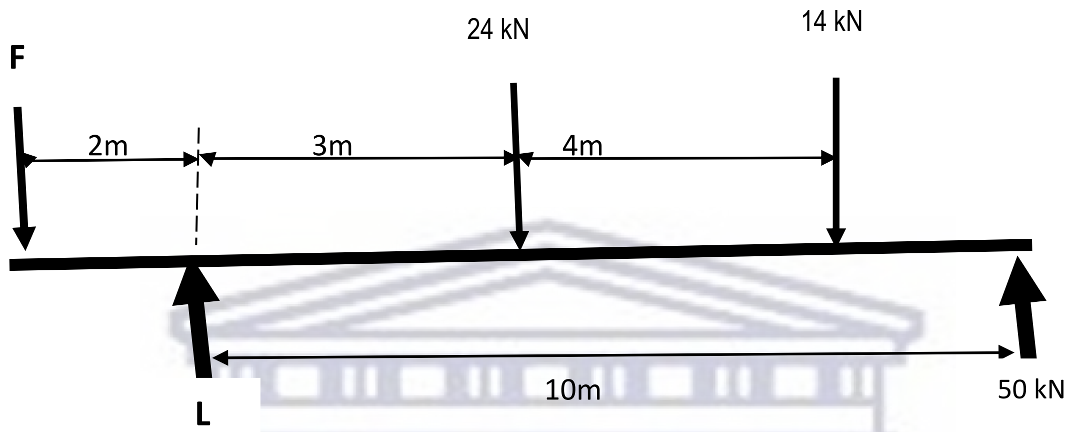
L = 135,417 N

Newton 3: **Upward forces = Downward forces**

539,583 + 135,417 = 245 + 110 + 320

LHS = RHS

2.2. Consider the **Figure** below, showing a beam supported by two supports **L** and **R**. Ignore the weight of the beam.



Calculate the value of the concentrated load **F** acting on the beam.

Moments about L:

(3x24) + (7x14) = (10 x -50) + (2 x F)

F = 335 kN

Met outcomes	Not Yet	Note that ...

3. Components of a force:

3.1. A force of 60 N is acting at an angle of to the horizontal. Determine the value of if the horizontal component of that force is 30 N.

$\cos\theta = 30/60 = \frac{1}{2}$

$\Theta = 60^0$

3.2. A force of 50 N, at an angle of 30° with the horizontal plane. Calculate the magnitude of the horizontal and vertical components of the force:

VC = 50 x $\sin 30^0$ = 25 N

HC = 50 x $\cos 30^0$ = 43,3 N

Met outcomes	Not Yet	Note that ...

APPENDIX 12: ENERGY - Worksheet

Student name/ Group name: .... / Individual / Group / Class /

Intra-argumentation (Individual) Inter-argumentation (Group)

1.1. Explain the meaning of the following terms and provide an example of each.

a) Kinetic energy –

Energy is the capacity to do work.

b) Potential energy –

Potential energy is the energy that a body possesses by virtue of its position or state of strain.

c) Mechanical energy –

Sum of kinetic energy and potential energy.

d) At which position will the pendulum have the most kinetic energy, explain?

At C, velocity is the greatest there.

e) Define linear momentum –

The product of mass and velocity of an object moving in straight line.

f) Define angular momentum –

The product of mass and velocity of a rotating object.

1.2. When a heavy book and a pen are dropped from the same height above the ground (if there is now air resistance), which of the two objects will hit the ground first? Explain your answer.

Both, gravitational acceleration does not depend on the mass of the object.

Met outcomes	Not Yet	Note that …

2. Complete the following exercises. Show all the calculations:

2.1 A crane is supporting a 40 kN load 35 m above the ground. The cable snaps and the load falls freely to the ground. Calculate the potential energy, kinetic energy and mechanical energy at the following positions:

Gravitational potential energy	*Kinetic energy*	*Mechanical energy*
a) At the top: PE = mgh = (40)(35) = 1 400 kJ	KE = 0	ME = 0 + 1 400 = 1 400 kJ
b) After falling 15 m: PE = (40)(35 - 15) = 800 kJ	KE = ME - PE = 1 400 – 800 = 600 kJ	ME = 1 400 kJ

Potential energy	*Kinetic energy*	*Velocity*

c) After falling 30 m:

PE = (40)(35 - 30)	KE = 1 400 – 200	KE = ½mv^2
= 200 kJ	= 1 200 kJ	v = 24,25 m/s

d) Just before it hits the ground:

PE = 0 J	KE = 1 400 J	V = 26,20 m/s

Met outcomes	Not Yet	Note that ...

2.2 A man with a mass of 75 kg sits on the rail of a bridge that is 50 m high across a river.

2.2.1 Determine the potential energy of the man on the bridge.

PE = (75)(9,8)(50) = 3 6750 J

2.2.2 If the man slips and falls, what would his velocity be, in km/h, just before hitting the water of the river?

KE = PE = ½mv^2 = 3 6750 = ½(75)v^2

V = 31,3 m/s

2.2.3 Calculate the momentum with which he strikes the water.

P = mv

= (75)(31,3) = 2 347,5 kg.m/s

Met outcomes	Not Yet	Note that ...

APPENDIX 13 – Lesson observation (Classroom talk)

Flanders' Interaction Analysis Categories (FIAC) – Group: _Experimental____

Teacher-talk (minutes): (18)37%	**0-10**	**11-20**	**21-30**	**31-40**	**41-50**
1. Accepting feelings: accepting and clarifying learners' feelings	*				
2. Praises and encourages learners' actions or behaviour.			*	**	
3. Accept or uses ideas and suggestions of learners.					
4. Gives facts or opinions about content or procedures.			*		
5. Asking questions about content, expecting learners to respond.	**		*	*	****
6. Give directions, commands or orders with which learners are expected to comply.	**		*	*	*
7. Criticises or justifies authority					
Learner-talk (minutes): (21)42%	**0-10**	**11-20**	**21-30**	**31-40**	**41-50**
1. Responses: talk by learners in response to teacher.	***		****	*****	***
2. Initiation: talk by learners, which they initiate.	**		**	*	*
Silence (minutes): (11)22%	**0-10**	**11-20**	**21-30**	**31-40**	**41-50**
1. Silence or confusion: pauses, or communication not understood by the observer.		***** *****			*

	Interactive	Non-interactive
Authoritative Focus on science's view	Presentation, Q and A I-R-F Teacher-learner-talk ≈ 1:1 (Teacher talk: 45-55%)	Presentation, Lecture Teacher-learner-talk ≈ 1.5:1 (Teacher talk: > 65%)
Dialogic Different points of view are considered	Probing, Elaborating, Supporting I-R-F-R-F Teacher-learner-talk ≈1:1.5 (Teacher talk: < 45%)	Review Teacher-learner-talk ≈ 1:1 (Teacher talk: 45-65%)

Note: I = initiation, R = response, F = feedback

Calculation:

Percentage talk *= frequency of talk ÷ 50 minutes x 100%*

Communicative framework of classroom talk: Group _Experimental____

1. Teacher-talk: 45-55% (Interactive and Authoritative) [____%]
2. Teacher-talk: >55% (Non-interactive and Authoritative) [____%]
3. **Teacher-talk: <45% (Dialogic and Interactive) [_37_%]**
4. Teacher-talk: 45-55% (Dialogic and Non-interactive) [____%]

Flanders' Interaction Analysis Categories (FIAC) – Group: _Control____

Teacher-talk (minutes):(29)58%	**0-10**	**11-20**	**21-30**	**31-40**	**41-50**
1. Accepting feelings: accepting and clarifying learners' feelings	*				*
2. Praises and encourages learners' actions or behaviour.					**
3. Accept or uses ideas and suggestions of learners.					*
4. Gives facts or opinions about content or procedures.		**	***	***	
5. Asking questions about content, expecting learners to respond.	**	*			***
6. Give directions, commands or orders with which learners are expected to comply.	***	**	***		
7. Criticizes or justifies authority				**	
Learner-talk (minutes):(16)32%	**0-10**	**11-20**	**21-30**	**31-40**	**41-50**
1. Responses: talk by learners in response to teacher.	*	***	****	****	***
2. Initiation: talk by learners, which they initiate.				*	
Silence (minutes):(5)10%	**0-10**	**11-20**	**21-30**	**31-40**	**41-50**
1. Silence or confusion: pauses, or communication not understood by the observer.	***	**			

	Interactive	Non-interactive
Authoritative Focus on science's view	Presentation, Q and A I-R-F Teacher-learner-talk ≈ 1:1 (Teacher talk: 45-55%)	Presentation, Lecture Teacher-learner-talk ≈ 1.5:1 (Teacher talk: > 65%)
Dialogic Different points of view are considered	Probing, Elaborating, Supporting I-R-F-R-F Teacher-learner-talk ≈1:1.5 (Teacher talk: < 45%)	Review Teacher-learner-talk ≈ 1:1 (Teacher talk: 45-65%)

Note: I = initiation, R = response, F = feedback

Calculation:

Percentage talk = *frequency of talk ÷ 50 minutes x 100%*

Communicative framework of classroom talk: Group _Experimental____

1. Teacher-talk: 45-55% (Interactive and Authoritative) [____%]

2. Teacher-talk: >55% (Non-interactive and Authoritative) [_58_%]

3. Teacher-talk: <45% (Dialogic and Interactive) [__%]

4. Teacher-talk: 45-55% (Dialogic and Non-interactive) [____%]

APPENDIX 14 - Focused Group Interviews

Focused Group Interview 1 (E-group: Distance versus displacement):

"Is it possible that distance and displacement can have the same magnitude? Explain"

E5: "It is impossible, because distance is always longer than displacement"

E12: "No, displacement is a straight line and distance is a crooked line"

The following is a group discussion (inter-argumentation) of Question 1.5 that took place in the group of students E5 and E12. The students were using dialogical argumentation protocol to reach consensus.

E10: "We need to know what the definitions of distance and displacement are first"

E12: "Distance is a crooked line and displacement is a straight line, therefore they can never be the same. If you walk home from campus, and say, fly home with an airplane, the distances will not be the same!"

E3: "No man E12, distance is not always crooked, like when you run a 100 meter they are both the same"

E5: "Ok, that makes sense, they are the same"

Group: "Yes! When the movement is in a straight line, they are the same"

Focused Group Interview 2 (E-group: Statics – moments):

The following excerpt illustrates how the construction of knowledge took within the ZPD framework - cognitive dissonance and equilibrium - within an inter-argumentation learning space, employing self-assessment and peer assessment. In this group discussion the students calculated and determined the magnitude of two supports that keep a horizontal beam in equilibrium, carrying different concentrated loads (Appendix 11: Statics worksheet, Question 2.2).

Student E3: "How did you guys used the law of moments? I always get it wrong!"

Student E6 [Using a ruler to act as the horizontal beam]: "The 25 kg load pushes the beam downwards, so it will rotate clockwise; and it is 3 m away from the left support. It will give us a clockwise moment of 25 times [multiplies with] 3".

Student E8: "No, my bro [brother]! We must first change the 25 kg to newtons; we are working with forces!"

Student E6: "Oh, yes! That's right, but the distance between the 110 N and 320 N is not given. Joh! I think there is a mistake in this question".

Student E10: "No, man! I think we need to subtract 4.5 m from the 7 m, which is given [written] below the horizontal beam. That will help to calculate the missing distance".

Group [after completing the calculations]: "Yes! The upward forces are equal to the downward forces!"

Focused Group Interview 3 (E-group: Energy – Falling load):

The following discussion demonstrates how mental shifts took place in terms of CAT. The students' responses also seemed to reveal that mental shifts took place resulting in improved understanding of the concept of conservation of energy. The discussion was about gravitational potential energy, kinetic energy and mechanical energy relating to a load falling from a certain height above the ground (Appendix 12: Energy worksheet, Question 2). The following discussion ensued to reach consensus during a Think-Pair-Share activity:

Student E7: "Let's see what is it that we have to do in this question and compare our answers."

[The students read the question and compares their notes]

Student E5: "When the cable of the crane snaps and the load falls, the potential and kinetic energy increase, because gravity pulls the crane down."

Student E7: "I don't agree with you! Potential energy will decrease because the height becomes less as the load falls down and the speed increases as it falls, therefore the kinetic energy increases."

Student E5: "Okay, it makes sense. When we use the formulas, potential energy depends on height which decreases; and kinetic energy depends on velocity which increases."

Focused Group Interview 4 (E-group: Attitudes towards DAAFLIM):

What do you guys think of the dialogical argumentation and the assessment activities?

In most of the activities, the students in the experimental group showed lots of interest and seemed to enjoy such activities in the way they interacted with each other and took part in the activities. The following positive views were expressed in one of the focus group discussions:

Learner E24: "I wish my maths lecturer could also teach us in this way"

Learner E8: "It is nice to work in groups and to debate about the work, now I understand it better"

Learner E15: "I have learnt that I cannot just give an answer, but have to motivate and give reasons why I say something"

Focused Group Interview 5 (C-group: Energy - Pen and book):

The following is a typical discussion that took place in one of the few group work sessions. The students called the educator to clarify a disagreement that arose among the students. They discussed the following question: *"When a heavy book and a pen are dropped from the same height above the ground, which of the two objects will hit the ground first? Explain your answer"* (Appendix 12: Energy worksheet, Question 1.2).

Student C12: "I think the book will reach the ground first! The book is heavier than the pen".

Students C18: "No, I don't think so; the pen will reach the floor first! The book is big and flat and will experience more air resistance!"

Student C14: "No, guys! They will both fall to the ground at the same time"

Student C16: "How is that possible C14? The book and the pen have different shapes and weights. I am really confused now"

[They call the educator who is walking nearby the group.]

Student C14: "Meneer, meneer [Sir, sir]! Please explain help us here!

Educator: [They explain their positions to the educator.] "Let me show you. Observe what is happening here". [He took a book and a pen from the table and dropped them from the same distance above the floor].

Student C12: "Okay, it looks like they both hit the floor at the same time, Sir!"

Student C16: “Yes, this is strange; they really reached the floor at the same time!”

Educator: “Well, now you must explain why it is the case”

Student C14: “I have seen an experiment like this on the TV once, with an iron ball and feather, where the both fall with the same speed in a vacuum room; they reached the ground at the same time. So, they fall with the same acceleration of gravity to the ground, because it [gravitational acceleration] is a constant.”

Student C18: “Yes, I see they both hit the floor together. But I still think the air resistance play a small role.”

Educator: “Yes C14, you are right. That is precisely what happens! I will explain this later to the whole class.”

Focused Group Interview 6 (C-group: Energy - Falling load):

The discussion was about gravitational potential energy, kinetic energy and mechanical energy relating to a load falling from a certain height above the ground (Appendix 12: Energy worksheet, Question 2).

Lecturer: “No, C1 why do you say that? Does anyone have a different answer and give a reason for your answer?”

Student C3: “Potential energy will become less, because it is directly proportional to the position above the ground and the kinetic energy will become more, because it is directly proportional to the velocity.”

Lecturer: “Ok! Let’s hear what the others have to say. Do you all agree with the answer of C3?”

Student C7: (Raises his hand up) "Yes sir, I agree with C3. Potential energy decreases, because the height decreases and its speed increases while it falls."

Lecturer: "Yes that's right, let's find out how it happens."

(The lecturer throws his pen in the upwards explaining how it relates to potential, kinetic and mechanical energy.)

Lecturer: (Pointing to the images on the electronic board) "Now, look! As you can see, the potential energy decreases and the kinetic energy increases, but the mechanical energy stays the same."

Class: (Some students exclaimed) "Ok, now we see!"

Focused Group Interview 7 (C-group: Components of a force):

The following group discussion between C-group students is analysed according to the TAP-protocol. The students were discussing how to calculate the components of a vector: "*A force of 50 N is at an angle of 30° with the horizontal plane. Calculate the magnitude of the horizontal and vertical components of the force*" (Appendix 11: Statics worksheet, Question 3.2).

Student C3: "We must first draw the 50N force in a right-angle triangle to find the other two sides".

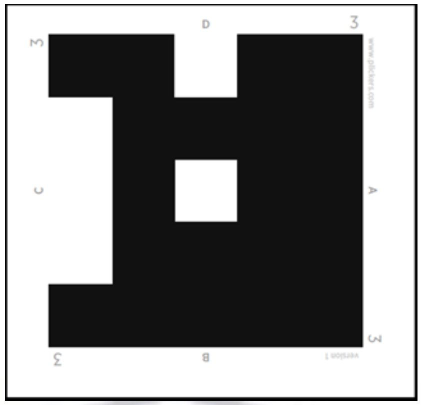
Student C7: "Okay, then we use sin and cos to find the components of the force".

Student C19: [Using a calculator] "The vertical component is 25N and the horizontal component is 43,3N".

Student C5: "Yes, it is right! If we use the Pythagorean Theorem give the same answer".

[The rest of the group nod their heads in agreement.]

APPENDIX 15 – Plicker card & quiz questions



The questions were based on particular lesson outcomes. For example, the questions for the lesson on dynamics:

1. Which of the following pair of quantities are vectors?

    a. Speed and velocity

    b. Time and distance

    c. Acceleration and velocity

    d. Displacement and time

2. Which of the following SI-units does **NOT** correspond with the quantities?

    a. Distance and meter

    b. Time and seconds

    c. Velocity and meters per second squared

    d. Speed and meter per second

3. Convert 120 km/h to m/s:

   a. 33,33

   b. 432,00

   c. 120

   d. 333,33

4. The slope of a velocity/time graph represents the … of the motion.

   a. Displacement

   b. Velocity

   c. Acceleration

   d. Speed

5. A stone thrown vertically upwards. What is happening with its kinetic energy?

   a. Increases

   b. Stays the same

   c. Does not have kinetic energy

   d. Decreases

6. When an object is in equilibrium, the resultant force is …

   a. Negative

   b. Positive

   c. Zero

   d. None of the above

7. The gravitational potential energy of a 3 kg ball 2 m above the ground is …

a. 6,0 J

b. 58,8 J

c. 60,0 J

d. 5,0 J

8. A force causing an object to rotate is called …

a. Resultant

b. Torque

c. Equilibrant

d. Friction

APPENDIX 16 – KWL worksheet

Name: ______________________________

Period: ______________________________

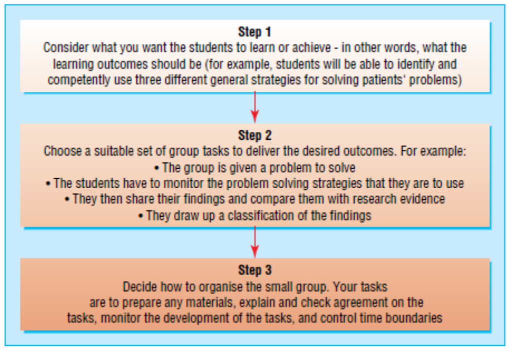
K-W-L Chart

Selection Title/Topic: ________________________________ Page #s: ____________

K What I Know	W What I Want to Learn	L What I Learned

APPENDIX 17 – DAAFLIM strategies

From Jaques (2003)



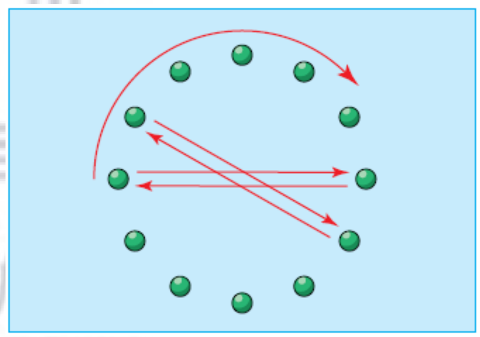
Fishbowls

The usual fishbowl configuration has an inner group discussing an issue or topic while the outer group listens, looking for themes, patterns, or soundness of argument or uses a group behaviour checklist to give feedback to the group on its functioning. The roles may then be reversed.

Fishbowl structure–inside group discusses, outside group listens in

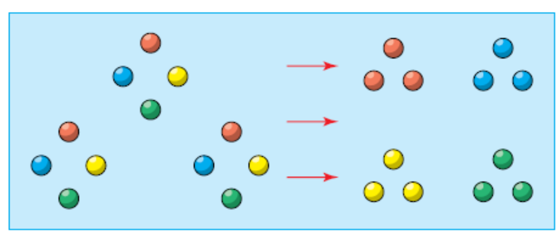
Circular questioning

In circular questioning each member of the group asks a question in turn. In its simplest version, one group member formulates a question relevant to the theme or problem and puts it to the person opposite, who has a specified time (say, one or two minutes) to answer it. Follow up questions can be asked if time permits. The questioning and answering continues clockwise round the group until everyone has contributed, at which time a review of questions and answers can take place. This could also include answers that others would like to have given. Alternatively, you or the students could prepare the questions on cards. You could also mix the best of the students' questions with some of your own.



Crossover groups

Students are divided into subgroups that are subsequently split up to form new groups in such a way as to maximise the crossing over of information. A colour or number coding in the first groupings enables a simple relocation—from, for example, three groups of four students to four groups of three, with each group in the second configuration having one from each of the first.



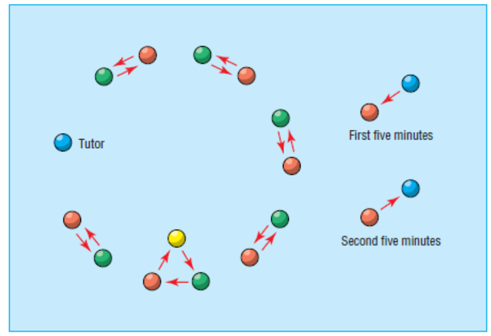
Crossover groups–redistribution of 12 students (each allocated one of four colours) for second period of session

Buzz groups

With larger groups a break is often needed:

- To provide a stimulating change in the locus of attention
- For you to gain some idea of what the students know
- For the students to check their own understanding.

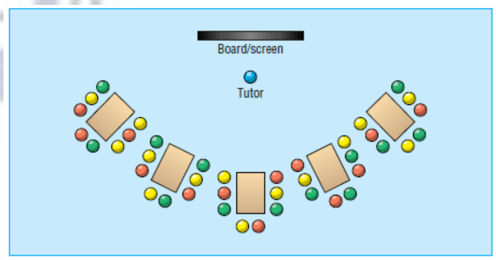
During a discussion students could be asked to turn to their neighbour to discuss for a few minutes any difficulties in understanding, to answer a prepared question, or to speculate on what they think will happen next in the proceedings. This will bring a sense of participation and some lively feedback. Buzz groups enable students to express difficulties they would have been unwilling to reveal to the whole class. (A variation is to allocate three or five minutes each way to the pairs—each phase is for one-way communication.)



Buzz groups, with pairs for one-way, five-minute communication

Horseshoe groups

This method allows you to alternate between the lecture and discussion formats, a common practice in workshops. Groups are arranged around tables, with each group in a horseshoe formation with the open end facing the front. You can thus talk formally from the board for a time before switching to presenting a group task. Subsequent reporting from each group can induce boredom. To avoid this danger, the tutor can circulate written reports for comment; get groups to interview each other publicly or get one member of each group to circulate; ask groups to produce and display posters; ask the reporters from each group to form an inner group in a fishbowl formation; or use the crossover method to move students around.



Horseshoe groups

Snowball groups

Snowball groups (or pyramids) are an extension of buzz groups. Pairs join up to form fours, then fours to eights. These groups of eight report back to the whole group. This developing pattern of group interaction can ensure comprehensive participation, especially when it starts with individuals writing down their ideas before sharing them. To avoid students becoming bored with repeated discussion of the same points, it is a good idea to use increasingly sophisticated tasks as the groups gets larger.

APPENDIX 18 – Certificate of editing

BAREFOOT TEACHER

CERTIFICATE OF EDITING

This certifies that the manuscript titled

Using Dialogical Argumentation and Assessment For Learning Instructional Model (DAAFLIM) to enhance students' conception of selected science topics at a college,

[Document original file ref: 'FG_PhD_30 September 2019_Final3.docx']

submitted by the author

Frikkie George,

has been edited for proper English language, grammar, punctuation, spelling and style by a competent editor at Barefoot Teacher. The veracity of sources cited and proper use of copyrighted material were explicitly excluded from the editing brief.

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N Lowe

Nazeem Lowe
Owner and Chief Editor

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