The Effects on Student Knowledge and Engagement When Using a Culturally Responsive Framework to Teach ASTR 101

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A thesis submitted to the Faculty of Natural Sciences at the University of the Western Cape in fulfillment of the requirements for the degree of Doctor of Philosophy.

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Abstract:

The U.S. has a problem: it is not effectively utilizing all the bright young minds available to its science & engineering workforce. In 2012 the President's Council of Advisors on Science and Technology (PCAST) reported that a million more STEM professionals in the U.S. workforce were needed over the next decade. PCAST reported that the situation is far worse for underrepresented students, who make up 70% of undergraduate students but only 45% of the STEM degrees. Recent reports suggest women in science and engineering have made small gains, while historically underrepresented ethnic groups (Blacks, Hispanics, American Indians) continue to be significantly underrepresented. The lack of diversity in the U.S. workforce is not reflected in the USA population nor is it reflected in the undergraduate student population. As the U.S. aspires to retain a leadership role in research and development in an increasingly diverse and globally interconnected society, this disparity is unsustainable.

What if having more culturally interesting, more culturally responsive STEM classes is a way of increasing the diversity of the science and engineering workforce in the U.S.? This study focuses on a topic that has been generally overlooked by the STEM educational community, but one that is directly relevant to student engagement and learning outcomes: the role of culture as a variable in student learning. This study examines how different pedagogical approaches shape student outcomes in Astronomy 101 courses. In a comparative study two different pedagogical approaches were analyzed using both quantitative and qualitative methods in a semi-experimental nonequivalent group research design. The theories of culturally responsive pedagogy (CRP), active learning theory in STEM, and Indigenous knowledge systems (IKS) ground this approach.

The findings of this study show important gains for all students. Underrepresented minority students (URM) in the course with increased culturally responsive pedagogy were exceptionally engaged and learning gains soared. By measure of the concept inventory, the URM students in the course with increased culturally responsive pedagogy outperformed all other students in the study.
As the U.S. will have a non-white majority by the year 2045 and diversity in STEM faculty lags there is a need for tangible, evidence-based, culture-based curriculum and pedagogy. There is a problem and based on the evidence found in this study, there is a way to fix it.

Declaration:

I confirm that this thesis presented for the degree of Doctor of Philosophy, Faculty of Natural Sciences at the University of the Western Cape, Department of Physics and Astronomy, has

i) been composed entirely by myself
ii) been solely the result of my own work
iii) not been submitted for any other degree or professional qualification

Printed: ______Annette S. Lee __________

Signature: ________________________

Date: July 1, 2020

Keywords:
STEM Higher education, Culturally responsive pedagogy (CRP), Culturally relevant pedagogy, Underrepresented Minority Students (URM), Astronomy Education, Cultural Astronomy, Indigenous astronomy, Indigenous Knowledge Systems (IKS), Indigenous Scientific Knowledge Systems, Active learning, Discipline-Based Educational Research (DBER)

Table of Contents

List of Figures

List of Tables

List of Abbreviations

<g>	normalized gain
A	active engagement
AAAS	American Association for the Advancement of Science
ADT	Astronomy Diagnostic Test
AER	Astronomy Education Research
AIP	American Institute of Physics
ANOVA	Analysis of Variation
ARC	Australian Research Council
ASTR 101	Astronomy 101 (Introductory College-level)
BioCats	biology learning catalysts
CAE	Center for Astronomy Education
CAER	Collaboration for Astronomy Education Research
CAPER	Conceptual Astronomy and Physics Education Research
CDAI	Cultural Diversity Awareness Inventory
COPUS	Classroom Observation Protocol for Undergraduate STEM
CR	culturally responsive
CRP	culturally responsive pedagogy
CRT	culturally responsive teaching
CRTOE	Culturally Responsive Teaching Outcome Expectancy
CRTSE	Culturally Responsive Teaching Self-Efficacy
DBER	Discipline-Based Education Research
EBIP	evidence-based instructional practices
EOP	Educational Opportunities Program
FERPA	Family Educational Rights and Privacy Act
FY	Fiscal Year
I&D	inclusion and diversity
IE	interactive engagement (active learning)
IEC	Independent Ethics Committee
IK	Indigenous knowledges
IKS	Indigenous knowledge systems
InTASC	Interstate New Teacher Assessment and Support Consortium
IRB	Institutional Review Board
IRR	inter-rater reliability
IRSSA	Indian Residential Schools Settlement Agreement
MEP	Minority Engineering Program
MI	multiple intelligence

MWP	Mathematics Workshop Program
NBPTS	National Board for Professional Teaching Standards
NCLB	No Child Left Behind Act
NIKSO	National Indigenous Knowledge Systems Office
NRC	National Research Council
NRF	National Research Foundation
NSF	National Science Foundation
OMB	Office of Management and Budget
PCAST	President's Council of Advisors on Science and Technology
PDP	Professional Development Program
PER	physics education research
PI	Peer Instruction
RAS	reticular activating system
RTOP	Reformed Teaching Observation Protocol
S&E	Science and Engineering
SCALE-UP	Student-Centered Activities for Large Enrollment Undergraduate Programs
SI	supplemental instruction
STEM	Science, Technology, Engineering, and Math
T	traditional teaching methods (lecture)
TDOP	Teaching Dimensions Observation Protocol
TEP	teacher education programs
TPI	Teaching Practices Inventory
TRC	Truth and Reconciliation Commission
TribCrit	Tribal Critical Race Theory
UNESCO	United Nations Educational, Scientific, and Cultural Organization
URM	underrepresented minority

Acknowledgements

A heartfelt acknowledgement to Jarita Holbrook and Delia Marshall for supporting this work. Without your time, effort, and expertise this would not have been possible. Many thanks to Hilarie Davis who shared her knowledge at exactly the moment it was needed. Special thanks to Noodin and Sagaigan, who were always available to take ice cream breaks.

This work is dedicated to my family, my community, and the seven generations (past and future).

Mitakuye Oyasin - To all my relatives

Chapter One: Introduction

Over the past several decades there has been much effort put into improving success rates of underrepresented minority students (URM) in higher education, particularly in STEM (Science, Technology, Engineering, and Mathematics) courses. Despite the enormous amount of research, programs, scholarships, and grants there is still a persistent gap between achievement rates for majority students and minority students. With the advent of active learning spearheaded by Eric Mazur (1997) and Richard Hake (1998) there has definitely been some learning gains, but still the gap persists. This study proposes that in order to address the root of the problem and thus create meaningful change, *the role of culture* in learning, particularly in learning science, must be examined.

This study compared student learning and engagement gains between two distinctly different types of instructional methods in an introductory college level astronomy course. Both courses implemented traditional (T) instructor-centered learning and interactive engagement (IE) student-centered learning deliveries. Both courses were taught by the same instructor that met three times a week for 50 minutes each over a 15-week semester. These were general education astronomy courses and not intended for majors. The study compared the students' performance between the course with increased culturally responsive pedagogy (CRP) (i.e. treatment course), and the control course.

Although the core science content was very similar, the culturally responsive (CR) course used curriculum and an approach aligned with culturally responsive pedagogy (CRP) which, as it will be shown, was informed by Indigenous knowledge systems (IKS). The key innovation of this study involved course design in the intervention class that used a culturally responsive framework.

1.1 General Background-Relevant Historical and Contextual factors

In the United States the Science, Technology, Engineering, and Math (STEM) workforce is in dire need, there are simply not enough young people going into STEM careers. This is despite the fact that STEM jobs command on average nearly double the pay of non-STEM jobs and STEM professionals experience lower unemployment (U.S. Bureau of Labor Statistics 2017). Why is the U.S. missing out on attracting all of these bright young minds into science fields that offer higher income, status, and opportunity? Studies show that many students that do well academically in introductory STEM courses still decide not to pursue STEM majors (Seymour and Hewitt 1997). At the same time U.S. society at large is becoming increasingly dependent on the products of science, technology, and engineering. What disadvantages in the competitive global economy will the U.S. face if it cannot sustain the number and quality of STEM research professionals in the current STEM workforce?

The landmark national report, "Report to the President-Engage to Excel" (PCAST 2012) concluded that in order for the U.S. to retain its historical excellence in science and engineering (S&E), the United States will need to increase the proportion of students who receive undergraduate degrees in STEM fields by 34% annually. This translates to one million more STEM professionals by the year 2022. In the U.S., fewer than 40% of intended STEM majors actually graduate with a STEM degree. Reasons that students give for migrating away from

STEM are uninspiring introductory courses, difficulty in math, and an unwelcoming academic culture in STEM especially for underrepresented groups (this includes women, Black, Hispanic, and American Indian populations) (PCAST 2012). Furthermore, women and minorities make up 70% of undergraduate students but only 45% of the STEM degrees (PCAST 2012). Non-white participation in STEM is disproportionately low. This represents a large pool of potential talent. With intentional focus on the first two years of college and the underutilized underrepresented the PCAST report made the following recommendations (PCAST 2012,16):

1. Catalyze widespread adoption of empirically validated teaching practices.
2. Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.
3. Launch a national experiment in postsecondary mathematics education to address the math preparation gap.
4. Encourage partnerships among stakeholders to diversify pathways to STEM careers.
5. Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.

PCAST found that one of the greatest barriers to change is the frequent and persistent use of lecture-style, passive learning in introductory STEM courses (PCAST 2012; Stains et al. 2018; Deslauriers, Schelew, and Wieman 2011; Gormally et al. 2009). Typically instructors teach the same way in which they were taught and so change is slow. Rewards for teaching excellence are few (Bradforth et al. 2015; Baldwin 2009). Some STEM faculty lack the awareness, experience, motivation, and resources that are needed in order to implement change in pedagogy (Mervis 2011; Bradforth et al. 2015; National Research Council 2015).

Other national reports such as: the National Science Foundation/American Association for the Advancement of Science "Vision and Change" report (U.S. National Science Foundation and American Association for the Advancement of Science 2009), and the National Research Council "Discipline-Based Education Research" report (U.S. National Research Council 2012) all concur there is a monumental and urgent need to more effectively teach STEM courses.

1.1.1 Undergraduate Women in Science

More recent reports based in the U.S. such as the "S&E Indicators 2018" (U.S. National Science Board 2018) suggest women in S&E have made incremental gains. For the past thirty years there have been more women than men pursuing undergraduate degrees. Undergraduate enrollment since 1993 had been at least 56% female (U.S. Department of Education 2018). And consequently on a continual basis over that past fifteen years more than half of all the bachelor's degrees in the U.S. are earned by women. For example, in both years 2000 and 2015, women were awarded 57% of the undergraduate bachelor's degrees in all fields (U.S. Department of Education 2018). Women are earning bachelor's degrees at parity with enrollment across all fields, but not within the sciences.

Roughly one-third of all bachelor's degrees are in S&E fields (31.8% and 33.9% respectively in years 2000 and 2015) (U.S. Department of Education 2018). What percent of these S&E bachelor's degrees are earned by women? And how has this changed over the past fifteen years? In both years 2000 and 2015 women earned approximately half of all the S&E bachelor degrees

(U.S. Department of Education 2018). Therefore women are underrepresented in S&E bachelor's degrees compared to overall enrollment (7 percentage points below parity or nearly a 25% difference).

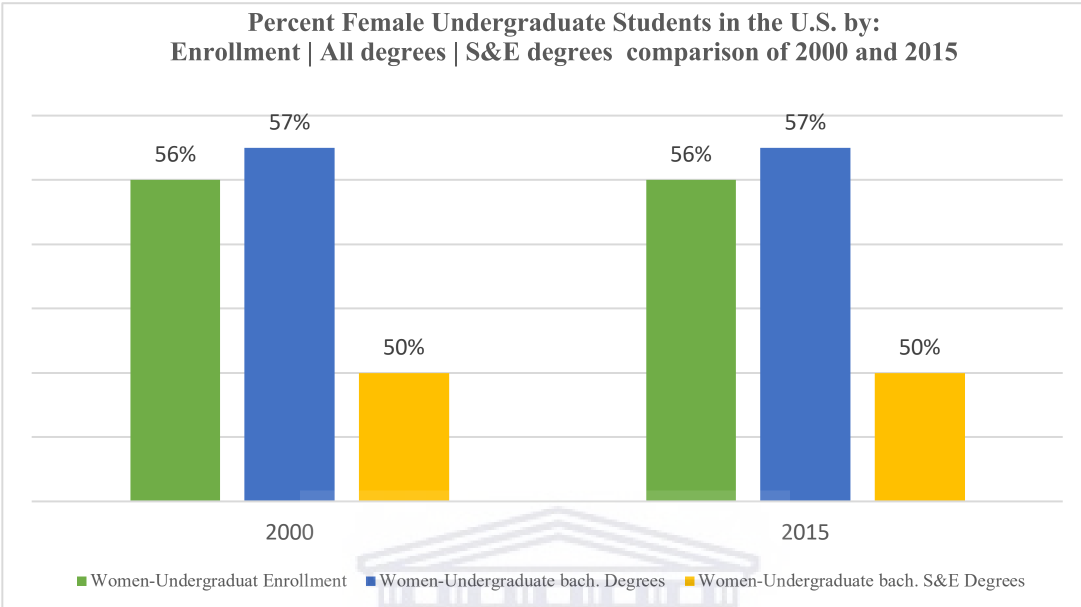
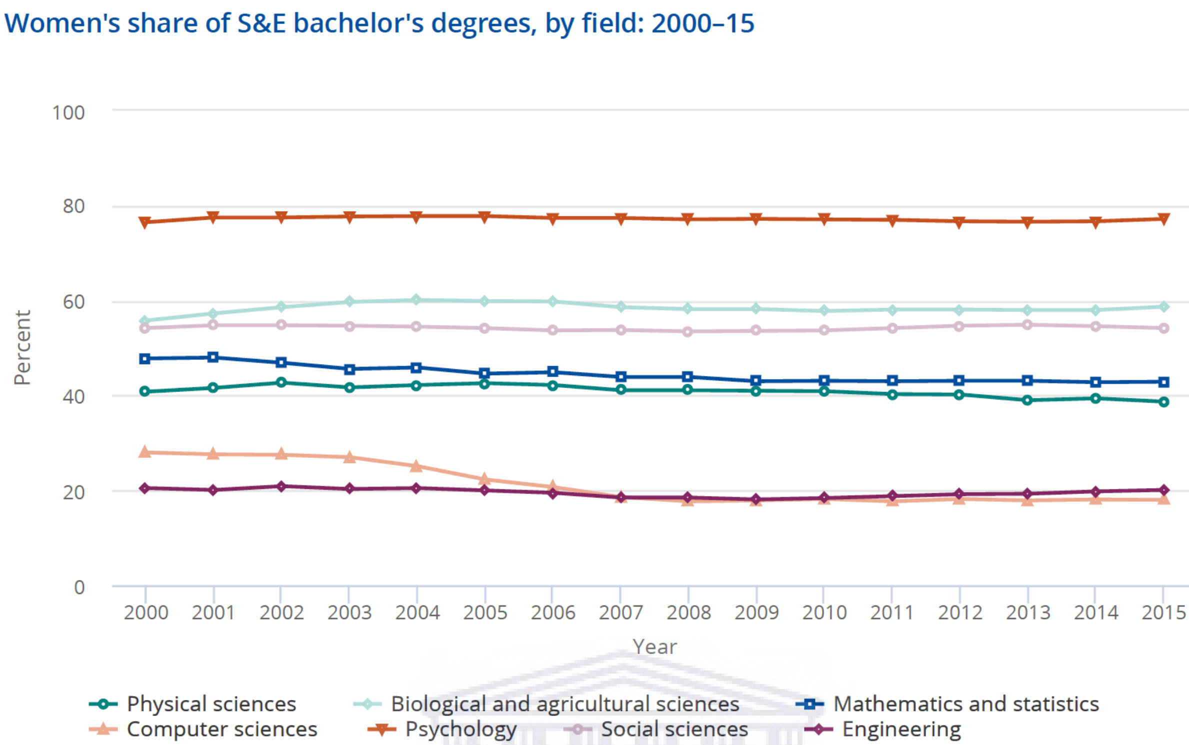


Figure 1 - U.S. Female Undergraduate Students, Source S&E Indicators 2018 (U.S. National Science Board 2018)

Incremental gains can be seen in specific S&E fields. For example, women made slight gains in psychology, biological sciences, agricultural science, and all the broad fields within social science except for economics. These gains were offset by men earning the majority of bachelor's degrees in: engineering, computer science, physics, and math/statistics (U.S. National Science Board 2018).

These statistics clearly show that the current system in STEM higher education is not working well for approximately half of the population. Both women and unrepresented minority students are the focus of this study.



Note(s)

Physical sciences include earth, atmospheric, and ocean sciences.

Source(s)

National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, https://ncsesdata.nsf.gov/webcaspar/.

Figure 2 - Female Science and Engineering Bachelor's Degrees (U.S. National Science Board 2018, 2-56)

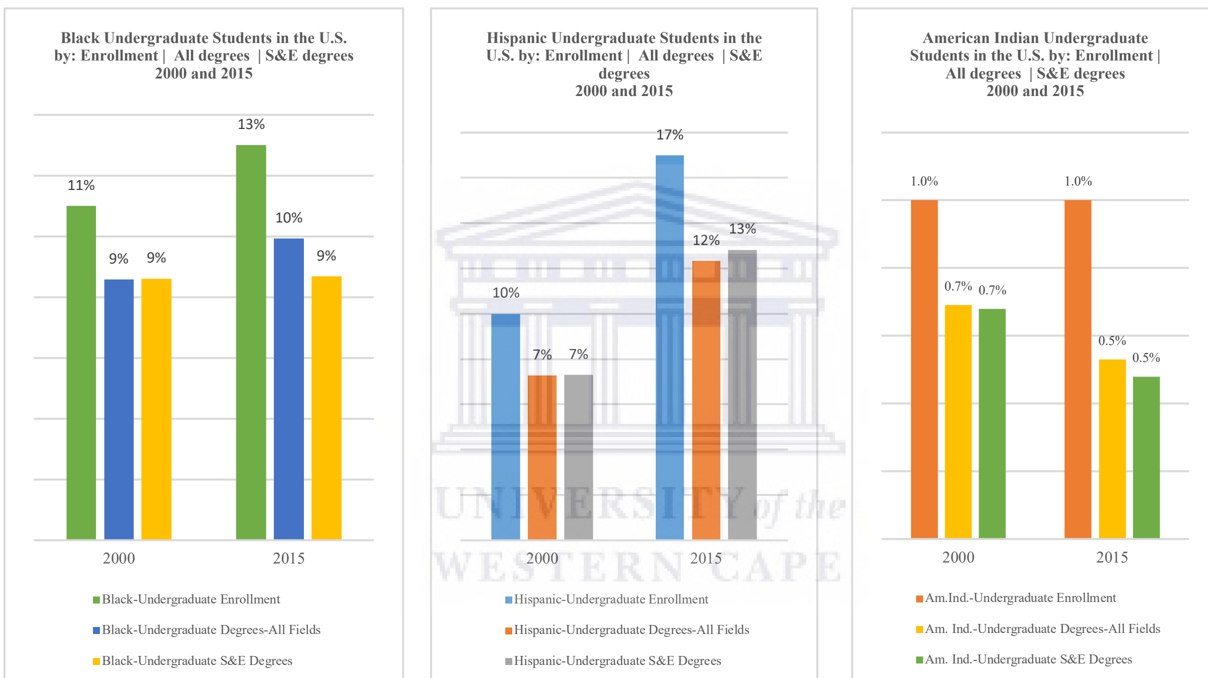
1.1.2 Undergraduate Underrepresented Ethnic Groups in Science

Historically underrepresented ethnic groups (Blacks, Hispanics, American Indians) continue to be significantly underrepresented in S&E. At first glance the trends seem somewhat encouraging, since the year 2000 the total number of S&E bachelor degrees attained has increased for most ethnic/racial groups (U.S. Department of Education 2018). More specifically a comparison over fifteen years show the following trends: 8.6% of the share of S&E bachelor degrees were earned by Black students in both 2000 and 2015; in 2000 the share of S&E bachelor degrees awarded to Hispanics was 7% and increased to 13% of the share in 2015; and in the year 2000 a total of 0.7% of the S&E bachelor degrees were earned by American Indian students and this decreased slightly to 0.5% in 2015 (U.S. National Science Board 2018). In summary, over this fifteen year period (2000-2015) S&E bachelor's degree attainments in the U.S. were as follows: Black students remained the same; Hispanic students increased; American Indian students decreased slightly. These totals include only U.S. citizens and permanent residents (U.S. National Science Board 2018).

When these numbers are compared to the undergraduate enrollment rates by race, the disparity can be seen more clearly. In the year 2015 the undergraduate student population by race in the

U.S. was as follows: Black 13%; Hispanic 17%; American Indian 1% (U.S. National Science Board 2018). Together the three historically underrepresented ethnicities represent 31% or about a third of the undergraduate students in the U.S.

For all three historically underrepresented ethnic minority groups, (Black, Hispanic, and American Indian students), the 2015 S&E undergraduate degrees earned are below parity with undergraduate enrollment. Black students are 4% below parity or a 36% difference; Hispanic students are 4% below parity or a 28% difference; and American Indian students are .5% below parity or a 67% difference. Taken together, the three historically underrepresented ethnicities in the year 2015 earned only 22.5% of the S&E bachelor's degrees. Therefore Black, Hispanic, and American Indian students are significantly underrepresented in S&E bachelor's degrees as compared to enrollment (8.5 percentage points below parity or nearly a 32% difference).



Figures 3, 4, 5 – Black, Hispanic, Am. Indian U.S. Undergraduate Students, Source S&E Indicators 2018 (U.S. National Science Board 2018)

Over time and slowly the racial and ethnic make-up of the S&E degree earning cohort is becoming increasingly diverse, reflecting the undergraduate population and enrollment increases for minority groups (U.S. National Science Board 2018). The fastest increase in undergraduate S&E degree achievement is the Hispanic population (U.S. National Science Board 2018). Note that in the year 2000 and again in 2010, a new way of classifying racial categories was added to the U.S. Census, 'Some Other Race' (U.S. Census Bureau 2012; 2001). This category includes all responses not in one of the five main categories of race: White, Black/African American, American Indian/Alaskan Native, Asian, Native Hawaiian/Pacific Islander. Also the number of S&E undergraduate degrees in the category 'Other/Unknown' nearly doubled in 2015 (U.S. National Science Board 2018). At the same time S&E bachelor degrees earners classified as 'White' is on a clear downward trend, from just over 70% in the year 2000 to nearly 60% of the S&E bachelor degrees in the year 2015 (U.S. National Science Board 2018).

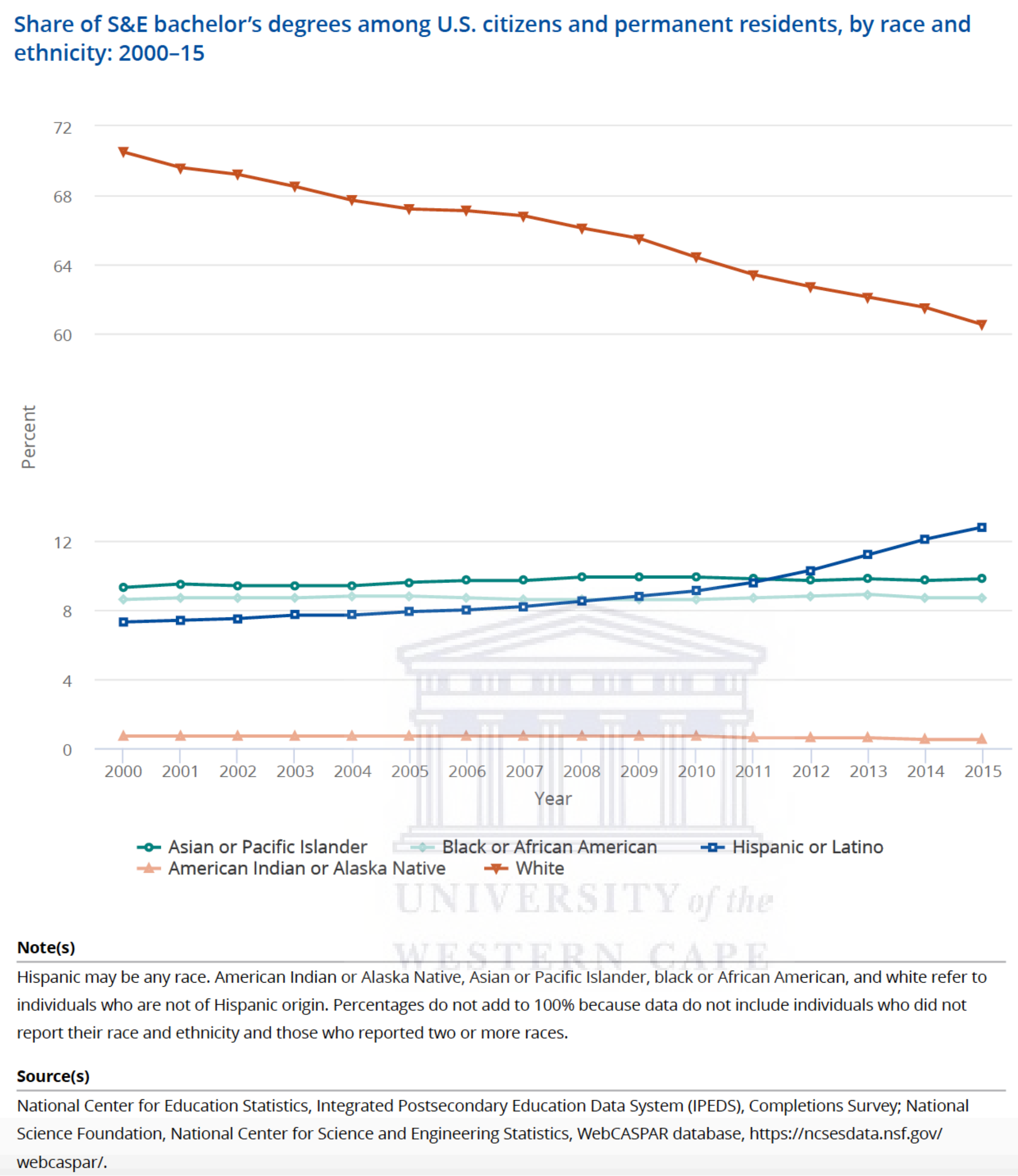


Figure 6 - Science and Engineering Bachelor's Degrees by Ethnicity (U.S. National Science Board 2018, 2-58)

As the statistical data clearly shows, the current efforts in STEM higher education are not working for underrepresented minority (URM) students in the U.S. This study will present course materials and approaches that explore a different way to address this loss of educational opportunity for nearly one-third of U.S. undergraduates, the Indigenous students (Black or African American, Hispanic or Latino, and American Indian or Alaska Native).

1.2 Research Objectives

The purpose of this project is to consider the cultural assumptions in teaching and learning pedagogy in science, and upon examination of the relationship of culture within science to ask the question, "What if the cultural underpinnings are different than the current norm, how does this effect learning and engagement?" In other words, what we do not know about the current state of undergraduate STEM education is *to what extent does culture influence the way students learn science*?

First, it is critically important to define culture. The general dictionary definition of culture is as follows: 'The distinctive ideas, customs, social behaviour, products, or way of life of a particular nation, society, people, or period' (Oxford English Dictionary 2008). This is a very generic description that focuses mostly on performative elements. Culture is much more than this in that it is often unconscious but has a huge impact on the philosophical underpinnings of a society. For the purposes of this study, the following definition of culture will be used:

> *Culture refers to a dynamic system of social values, cognitive codes, behavioral standards, worldviews, and beliefs used to give order and meaning to our own lives as well as the lives of others.*
>
> *Even without our being consciously aware of it, culture strongly influences how we think, believe, communicate, and behave, and these, in turn affect how we teach and learn. Because teaching and learning are always mediated or shaped by cultural influences, they can never be culturally neutral.* (Gay 2000, 8)

This research addresses the question: how can non-Western European culture be integrated into STEM curriculum? And most importantly, how does this cultural integration within an introductory astronomy course affect student success and engagement?

Research shows that active learning engagement supports positive learning gains for underrepresented groups in STEM (Hrabowski 2011; Haak et al. 2011; Mervis 2010; Eddy and Hogan 2014). Research in K-12 learning environments shows that culturally responsive pedagogy supports positive learning gains for underrepresented groups in STEM (Larke 2013; Klug 2012; Gay 2018; Rowland and Adkins 2003; Castagno and Brayboy 2008; Irvin and Darling 2005). How can we apply culturally responsive teaching to STEM courses at the undergraduate level? As we look to culture to inform our practice of teaching, can these insights also benefit the majority culture? Additionally, what are tangible examples, both instructional and curricular, of what instructors of ASTR 101 can do to be more culturally inclusive?

The primary goal of this research is to answer the question:

To what extent will ASTR 101 students, particularly underrepresented[1] *groups in STEM, be more engaged and show positive learning gains when culturally inclusive content and culturally responsive instructional strategies are implemented?*

The main objectives of this research project are the following:

I. measure the effectiveness of culturally inclusive ASTR 101 lessons, with emphasis on level of engagement and positive learning gains, particularly for underrepresented groups in STEM
II. produce samples of classroom ready, undergraduate introductory astronomy (ASTR 101), curriculum materials that contain increased culturally inclusive content

[1] Note: 'Underrepresented groups in STEM' are defined here as underrepresented minority (URM) students of African-American, Hispanic-American Native American, African (not American), and Multicultural ethnicities/race.

In view of the established aims and objectives, this study attempts to provide responses to the following three key questions:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*
- *How does culturally inclusive curriculum qualitatively and quantitatively affect knowledge acquisition for ASTR 101 students?*
- *Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?*

1.3 Significance of this Research

Why is diversity in STEM important? The first reason why broadening participation in STEM is important is a moral argument: equity and fairness. Why should a person's race and/or ethnicity and/or gender determine whether a young person will have the opportunity for a science career or not? Shouldn't everyone have this opportunity?

A brief look at the history of the U.S. in terms of diversity reminds us of two important markers. Beginning in the late 16th century England, France, Spain, and the Netherlands launched major colonization initiatives to the United States where the land was already occupied by over 700 Indigenous language groups and tribal cultures. European colonization led to massive mortality rates, slaughtering of culture, overtaking the land, massive disease diffusion, and in some cases extinction. Pandemic diseases like smallpox, measles, and typhus spread like wildfire across the land before the invading troops and colonists arrived. By some estimates, over a two hundred year period, up to 95% of the Indigenous population was annihilated: "In 1491, about145 million people lived in the western hemisphere. By 1691, the population of Indigenous Americans had declined by 90-95 percent, or by around 130 million people" (McKenna and Pratt 2014, 375).

Land acquisition and slavery were the economic foundation of the 'Americas'. First Native Americans were used as slaves, then enslaved Africans were brought to the Americas. From 1492-1865 slavery was profuse on American soil. Human beings, Indigenous peoples from West Africa, Central Africa, and some from East Africa were bought, sold, tortured, slaughtered, beaten, and commodified in some of the worst atrocities in the history of the U.S. In 1820 Thomas Jefferson wrote his thoughts on slavery in a letter, "We have the wolf by the ear, and we can neither hold him, nor safely let him go. Justice is in one scale, and self-preservation in the other,*"* (Jefferson 1820). Both atrocities, colonization and slavery, were sustained in part by the idea of 'necessary evil' and fear that change would cause harmful social and economic consequences.

The trail of historical inequalities in the U.S. educational system dates back to at least 1830 where most southern states had laws forbidding teaching people in slavery to read. Another layer of historical trauma was enacted in 1879 by the Indian boarding schools. Native youth were forcibly taken from their parents, forced to abandon their culture and language among other horrors. Then the landmark book, "The Passing of the Great Race" (Grant 1916) debuted purporting the 'Nordic' race as inherently superior to other races such as 'Mongoloids' and 'Negroids' and further paved the way for eugenics and scientific racism in the U.S. Another example of racism ingrained in the U.S. educational system was the implementation of the standardized IQ test. The standardized intelligence test was created by French psychologist

Alfred Binet in late nineteenth century and introduced in America by Henry Goddard. Early tests were first implemented on World War I recruits in the late nineteenth century in the U.S. Army (Au 2016, Gould 1996). Lower average test scores of African Americans that lived in the southern states were widely publicized and used to promote racial inferiority by whites, in spite of the fact that African American who lived in the north on average scored higher than even whites in the south (Hammersmith 2015). In 1931, Alvarez versus the Board of Trustees of the Lemon Grove School District of California school eliminated school segregation with Mexican-American students, and represented the first successful school desegregation in the U.S. Finally in 1954, Brown versus Board of Education of Topeka was unanimously passed by the U.S. Supreme Court ruling that segregated schools are 'inherently unequal' and must end. The historical context highlights the importance and the ongoing struggle of working towards equity in the American education system. The roots of the educational system are layered with inequity and exclusion. Today sixty-five years later educators, researchers, teachers, individuals, and communities strive to broaden participation in science because it is the only morally and ethically correct action.

A second reason for diversity in STEM Higher Education has to do with the numbers. The U.S. is quickly becoming more ethnically/racially diverse. This is an undeniable fact. The 2010 U.S. Census reported a population of 308.7 million people. The United States is the third most populous country in the world (U.S. Census 2010) and home to many diverse communities both racially and ethnically. The U.S. Census Bureau officially recognizes the following racial groups: White American 72.4%; Black or African American 12.6%; Asian American 4.8%; American Indian and Alaskan Native 0.9%; Native Hawaiian and Other Pacific Islander 0.2%; Some Other Race 6.2%; Two or more races 2.9% (U.S. Census Bureau 2011). Note that 'White' is defined as 'having origins in any of the original peoples of Europe, the Middle East, or North Africa'. 'Black or African American' is defined as 'people with origins in any of the Black racial groups of Africa'. Hispanic and Latino Americans at 16.3% of the population are not considered one of the official racial categories but are instead defined as 'an ethnic group of people from Latin America, Spain, and Portugal'. 'American Indian or Alaska Native' refers to a person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment. This category includes people who indicated their race(s) as 'American Indian or Alaska Native' or reported their enrolled or principal tribe, such as Navajo, Blackfeet, Inupiat, Yup'ik, or Central American Indian groups or South American Indian groups (U.S. Census 2010).

Compared to other countries, the United States' methods of counting majority and minority populations is very broad, with wide-ranging categories, that leaves plenty of room for improvement and discussion. Population projections published by the U.S. Census Bureau (U.S. Census Bureau 2015) demonstrate that the 'non-Hispanic White alone' racial category (i.e. European Americans, Middle Eastern Americans, and North African Americans) is currently the majority but by 2060 will fall down to 44%. This means that the U.S. will become a 'majority minority' country in approximately 2044: "no group will have a majority share of the total and the United States will become a "plurality" of racial and ethnic groups." (U.S. Census Bureau 2015:9)

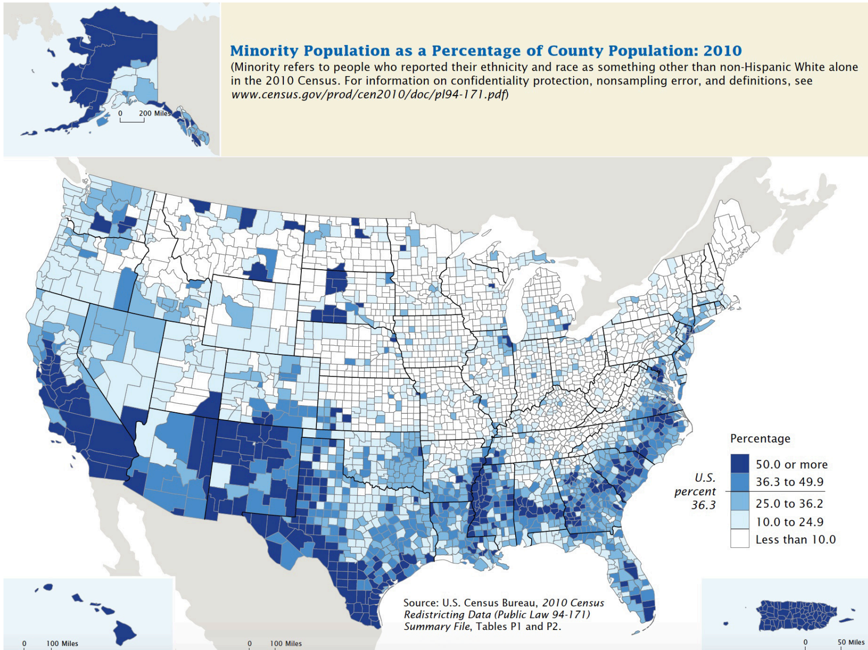


Figure 7 - U.S. Minority Population, data from the 2010 Census (U.S. Census Bureau 2011, 20)

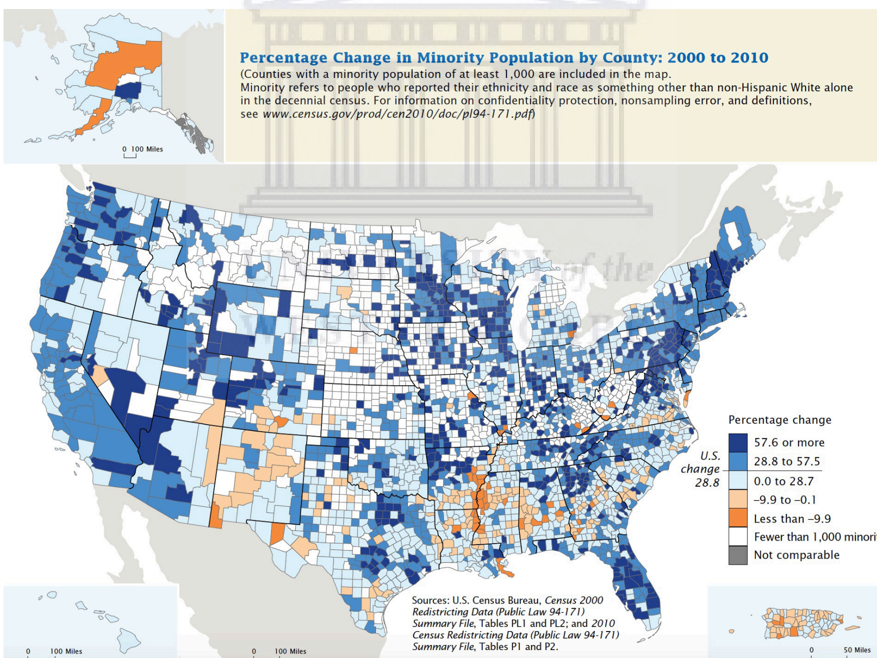


Figure 8 - Change in U.S. Minority Population, data from the 2010 Census (U.S. Census Bureau 2011, 21)

Interestingly, a sixth category was added in the 2000 census, 'Some Other Race'. This category is defined by the following, "all other responses not included in the White, Black or African American, American Indian or Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander race categories described above. Respondents reporting entries such as multiracial, mixed, interracial, or a Hispanic or Latino group (for example, Mexican, Puerto Rican, Cuban, or Spanish) in response to the race question are included in this category" (U.S. Census 2010). Furthermore, individuals who chose more than 1 of the 6 race categories are referred to as the 'Two or More Races' population. All respondents who indicated more than one race can be collapsed into the 'Two or More Races' category which, combined with the six race-alone categories, yields seven mutually exclusive and exhaustive categories. Thus, the six race-alone categories and the 'Two or More Races' category sum to the total population. The category 'Two or More Races' is expected to be the fastest growing racial group and will triple by the year 2060 to 26 million people or 6.2% of the U.S. population (U.S. Census Bureau 2015). All the evidence points to an increasingly diverse culture in the U.S., this includes the general population and also K-12 and college/university levels. As this demographic transformation is happening there is also the need to shift from the mindset of assimilation of cultures into the 'great American melting pot' to the mindset of cultural awareness, cultural agility, and intercultural/global fluency.

A third reason why diversity is essentially important is the potential to do better science. The National Science Foundation (NSF), one of the top U.S. federal funding agencies with an annual $7.8 billion budget, FY18 (U.S. National Science Foundation 2018b), that supports all science research and education (except medical fields which is funded by the National Institutes of Health) acknowledges diversity as one of the continuing five-year priorities. As clearly stated, "NSF is committed to leading the way to an enterprise that fully captures the strength of America's diversity" (NSF 2006). In the Strategic Plan 2018-2022 NSF prioritizes "effective approaches to preparing a diverse, globally competitive STEM workforce and a STEM-literate citizenry" and "NSF is committed to broadening participation by .. expanding efforts to broaden participation from underrepresented groups and diverse institutions across all geographical regions in all NSF activities…" (U.S. National Science Foundation 2018a, 20). And more to the point:

> *The effectiveness of NSF's investments to contribute to the Nation's STEM workforce through research training depends on the inclusion of people who traditionally are underrepresented in the scientific enterprise. A STEM workforce that reflects the diversity of our society is essential for the emergence of a rich set of ideas and approaches that drive discovery and innovation in a way that would be impossible without this diversity.* (U.S. National Science Foundation 2018, 22)

Widening the diversity of participation in science is not viewed by the NSF as an option for an idealized future, but as a critical and urgent necessity for driving innovation in science that would otherwise be impossible. The author of this study concurs.

In addition to government agencies, businesses are recognizing the importance of diversity. A report entitled, "Diversity Matters", summarized research done by the McKinsey Company, a major consulting firm (Hunt and Prince 2015) showed that gender-diverse companies were 15% more likely to outperform their competitors and ethnically diverse companies were 35% more likely to outperform competitors. This was labeled 'Diversity's Dividend'. Furthermore, companies in the bottom quartile in these diversities were statistically less likely to achieve returns above the national industry median. This research included 366 public companies in the U.S., Canada, United Kingdom and Latin America. Following this was a larger study entitled, "Delivering through Diversity" (Hunt et al. 2018) that reaffirms these results correlating financial gains and diversity inclusion. Over 1,000 companies in 12 countries were studied using measures of performance profitability and economic profit margin and the study concluded that companies in the top quartile of gender and cultural diversity were 21% and 33% more likely to outperform competitors. There is a growing awareness that inclusion and diversity (I&D) allows businesses to succeed, grow, and have a competitive edge (Hunt et al. 2018). As the academic model increasingly blends with the business model in these times of financial challenges for many educational institutions, it seems reasonable that the data showing a statistical connection between increased diversity and increased efficacy holds true for academic establishments as well as corporate firms.

Finally, in addition to moral arguments, the undeniable demographics, and simply just doing better science, there is a big picture reason for increasing participation of diverse groups in science: science literacy and leadership. According to the Science & Engineering Indicators report 2016 members of the U.S. public are “more likely to have a great deal of confidence in leaders of the scientific community than any other group except the military” (U.S. National Science Board 2016). How can underrepresented students attain leadership positions in STEM, in their communities, in policy making decisions, and in the workforce if the barriers are insurmountable? As the U.S. aspires to retain a leadership role in research and development in an increasingly diverse and globally interconnected society, this disparity is unsustainable. On an individual level, each person’s ability to contribute to society with a basic level of science literacy and the ability to practice critical reasoning is fundamental to the overall health and sustainability of society. A healthy society also has non S&E majors with a basic understanding of math and science (Impey et al. 2011). They are informed citizens who practice critical thinking.

1.4 Limitations of this Study

One of the limitations that this study faces is the complexities of defining race in the U.S. The U.S. Office of Management and Budget (OMB) guidelines are implemented by the U.S. Census Bureau. These are the U.S. government offices that are responsible for defining categories of race and ethnicities on collection of federal data. As of 1997, and as implemented in 2003, the new standard requires that on every government survey on race-ethnicity there must be a minimum of five racial categories: American Indian/Alaskan Native, Asian, Black/African American, Native Hawaiian/Pacific Islander, and White. In addition there must be a minimum of one ethnicity question: Hispanic or not Hispanic. Two important details are as follows: (1) White is defined as ‘A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.’; and (2) Hispanic is defined an ethnicity and not a race. The definition of Hispanic is: ‘A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin regardless of race’ (U.S. Census Bureau 2011, 3). Notice a person who identifies their origin as Hispanic, Latino, or Spanish may be of any race. Both of these categories, White and Hispanic, have been challenged and criticized. Also not obvious is that the category of American Indian/Alaska Native includes ‘people with origins in any of the original peoples of North and South America (including Central America)’ (U.S. Census Bureau 2011, 3). Further challenges related to the consistency of the data arise from self-identification, the allowance of multiple responses, and the uncertainties introduced with the classification of ‘Some Other Race’ and ‘Two or more races’ implemented in 2000 and 2010 (U.S. Census Bureau 2012). Some surveys give the option to select more than one race; some do not. In this study, within an introductory astronomy course, data on ethnicity and race was gathered entirely from the concept inventory assessment tool. Here the choices were: White (not Hispanic), Asian (not American), Asian-American, African-American, African (not American), Hispanic-American, Native American, Multicultural, None of the above. Consequently, data based on race is subject to inconsistencies.

The sample size of this study (approximately 500 students) was another limitation. Participants were self-enrolled in one of the following college level introductory astronomy classes: ASTR 106-Concepts of the Solar System or ASTR 107-Concepts of the Stars and Universe. Both classes were taught by the same instructor, face-to-face over a 15-week semester at a regional comprehensive public university located in the Midwestern United States. Further studies with larger sample sizes and done at multiple universities across several STEM disciplines involving several instructors would be ideal for second and third-generation studies.

Another limitation is student self-reported data. Response rates for anonymous student surveys are usually less than 50%. Students may feel overwhelmed with survey and feedback requests, and do not want to participate, they experience 'survey fatigue'. Also students might distrust the anonymity of the survey and believe that it will affect their grade negatively. Responses could be positively inflated. On the other hand, students could have the opposite approach and respond with quick, unthoughtful answers in order to reach completion.

And finally a limitation that must be taken into account is the Hawthorne effect, or when participants' behavior is changed because they are cognizant of being observed (McCambridge, Witton, and Elbourne 2014; Monahan and Fisher 2010). Also known as the 'observer effect', this behavior by research subjects was first noticed in a study done in the 1930s at a Western Electric factory near Chicago. Employers wanted to know if workers would be more productive or less productive with varying amounts of lighting. For small increases in illumination, productivity increased. This was deemed a temporary effect, motivated by the workers awareness of being observed. The implication in this study would be if the act of observing the students during an actual class would change their behavior. Although entirely possible, this would be a small effect and the same bias would appear for both the control and the treatment courses as they were both observed in equal overall amounts and using the same protocol.

Chapter Two: Relevant Concepts

Some people assume that one of the greatest strengths of science is that it is impartial. Science defines objectivity. They would argue that science is a universal truth, a set of laws that exist above and outside of humanity in which the tools of the scientific method are applied to nature in an attempt to discover order. But is science completely objective? And more to the point, is science devoid of culture? What cultural assumptions might exist at the very foundation of science? Scholars like Sandra Harding (2016) have argued that not only is science embedded with Western ethnocentrism, but it goes further to infer "that only practitioners of Western scientific rationality exercise critical reason" (98). This section examines the cultural underpinnings of science. Critical questions are: how is science defined and by whom? What cultural assumptions are embedded in the discipline of science?

This chapter presents alternate ways of knowing and experiencing the natural world, from non-Western perspectives, or Indigenous cultures' practice of science. It makes sense "that there is not just one universal form of knowledge (Western science), but a variety of knowledges" (Turnbull 2000, 1). And to be clear, "…this presumed objectivity and universalism of Western science rationalizes our failure to acknowledge other ways of knowing" (Brayboy and Castagno 2008, 17). Science in the last six centuries has become increasingly restrictive and progressively narrow. This narrowing has been used to serve the needs of the dominant culture.

2.1 Indigenous Knowledge Systems

Indigenous knowledges (IK), Indigenous knowledge systems (IKS), and curriculum reform are contemporary areas of research worldwide, especially in relation to science education and decolonizing science. The definition of Indigenous knowledge systems (IKS) used in this study is as follows:

> *Indigenous knowledge system (IKS) compromise knowledge systems that have developed within various societies' independent of, and prior to, the advent of the modern scientific knowledge system. IKS from various cultures evolved into broad and comprehensive knowledge systems….that addressed societal and traditional knowledge issues in various fields important to human survival and the quality of life…*(Tharakan 2015, 52)

In 1999 the United Nations Educational, Scientific, and Cultural Organization (UNESCO) in conjunction with the International Council for Science (ICSU) held a World Conference on Science. The resulting report urges global governments to support and promote understanding of Indigenous knowledge systems (IKS). First outlined in the Preamble, "All cultures can contribute with valuable scientific knowledge" (UNESCO 2003, 9), with greater detail the report states:

> *…traditional and local knowledge systems, as dynamic expressions of perceiving and understanding the world, can make, and historically have made, a valuable contribution to science and technology, and that there is a need to preserve, protect, research and promote this cultural heritage and empirical knowledge.* (UNESCO 2003, 14)

The report goes on to urge the scientific community to support, create dialogue, and build relationships, with "traditional societies and philosophers from all countries" (UNESCO 2003). Specifically:

> *Modern science does not constitute the only form of knowledge, and closer links need to be established between this and other forms, systems and approaches to knowledge for their mutual enrichment and benefit. A constructive intercultural debate is in order to help find ways of better linking modern science to the broader knowledge heritage of humankind.* (UNESCO 2003, 40)

The recommendation is for scientists to respect, sustain, and enhance traditional knowledge systems and that traditional knowledge should be integrated into interdisciplinary projects. Clearly the world's leading voice in science, education, and culture, UNESCO, understands the importance of widening the lens of science.

South African work in Indigenous science education has been supported by a broader initiative of the Truth and Reconciliation Commission of South Africa (TRC) which was legally established in 1995 under the Promotion of National Unity and Reconciliation Act No. 34 after apartheid was formally abolished in 1991. The TRC of South Africa was an attempt to recognize, record, and begin to repair some of the damage done by institutional racial segregation of apartheid, a system that officially lasted from 1948 to 1991. Later the Institute for Justice and Reconciliation was established to continue the work of TRC. Although the efficacy of the TRC was debated, it did help to create a pathway for Indigenous knowledge systems (IKS) in South Africa. Recognition of Indigenous knowledge systems, including the practitioners and holders of Indigenous knowledge, grew in strength in 2004 when the Indigenous knowledge systems (IKS) Policy was approved at the federal level. The preamble states:

> *The Government of the Republic of South Africa registers its commitment to the recognition, promotion, development, protection and affirmation of IKS. This Policy is the product of extensive consultation, scholarly reflection, debate and participation from a range of stakeholders. The participation of practitioners and holders of Indigenous knowledge (IK) has been of critical importance.* (Department of Science and Technology-Republic of South Africa, 2004, 6)

Two years later, the National Indigenous Knowledge Systems Office (NIKSO) was started within the Department of Science and Technology. These national actions laid the groundwork for revitalizing and protecting IKS in South Africa. As further explained in the IKS Policy:

> *Under apartheid, IKS in South Africa, as well as practitioners within such systems, were marginalized, suppressed, and subjected to ridicule. This had profound negative effects on the development of South Africa's economy and society, resulting in the distortion of the social, cultural and economic development of the vast majority of its people*. (Mangena, Hanekom, and Adam 2004, 10)

And concludes:

> *This IKS policy is historic in the sense that it affirms African cultural values in the face of globalization. Its provisions are intended to affirm, recognize, protect, promote and develop IK held by Indigenous and local communities for the purpose of economic growth and social development. It is underpinned by the key drivers such as the contribution of IK to the economy and the interfacing of IKS with other knowledge systems.* (Mangena, Hanekom, and Adam 2004, 36)

Later the Minister of Science and Technology, Naledi Pandor, speaks to the issue of commodification of culture and urges a 'technology of humility' approach which means to consider who benefits and who might be hurt (2016). He explains this is in lieu of the current approach based on Western science of 'command and control' approach (Pandor 2016).

The South African government funds research through the National Research Foundation (NRF) and this includes both disciplines of Astronomy and Indigenous knowledge systems. One caveat of the funding for IKS is that an Indigenous knowledge keeper must be included as a principle or co-principle investigator on all grant applications without exceptions (NRF 2018) and has proven to be a barrier in this funding pathway (Holbrook 2016). Another challenge presented is that the system of Western academia laden with abstraction creates a contradiction for Indigenous African students who are sometimes aligned to a more holistic and community based ways of knowing (Kaya and Seleti 2013). African Indigenous scholar Ngugi wa Thiong'o stressed that decolonizing the mind should include Indigenous knowledges not as an add-on or an alternative knowledge but as one way of knowing among many ways of knowing (1986).

In the twenty-five years since South Africa has been a democracy a lot of effort has gone into reforming the educational system, and in particular science education. The idea of "cognitive imperialism" (Shizha 2008, 82) is recognized in African schools where alternative ways of knowing are denigrated (Msimanga and Shizha 2014) as nonsense or discarded altogether (Mawere 2015). Indigenous African scholars like Munyaradzi Mawere (2015) and Lesley Le Grange (2007) outline the assumptions underlying both the Indigenous knowledge system and the Western science system. Mawere's differences between conventional science and Indigenous knowledge includes: written versus oral means of transferring information; academic versus local contexts/place-based knowledge; permanent versus constantly changing knowledge; and individual competitiveness versus communal cooperation in learning (2015).

> *…as long as Indigenous knowledge fails to find full recognition within and real integration into curricula and the mainstream knowledge discourse, the lofty pan-African ideals of collective self-reliance, self-sustaining development, and economic growth will remain an unrealized dream.* (Mawere 2015, 67)

Similarly, Le Grange highlights various worldviews embedded in Indigenous knowledge Systems and Western science, adapted from earlier research done by Meshach Ogunniyi (2005):

> *Nature is real and partly observable versus nature is real and observable; events have both natural and unnatural causes versus all events have natural causes; the universe is partly predictable and partly unpredictable versus the universe is predictable; language is important as a creative force in both the natural and unnatural worlds versus language is not important to the workings of the natural world; knowledge is a critical part of culture versus science is culture free; and*

> *humans are capable of understanding only part of nature versus humans are capable of understanding nature.* (Le Grange 2007, 585)

An underlying theme here is that "representations of Western science are used as criteria for declaring 'other' knowledges as non-science" (Le Grange 2007, 586) and this creates a "cognitive dissonance" for the South African science learner (Le Grange 2007, 588).

Furthermore, the enduring field of Cultural Astronomy, as defined "the study of humans and their relationship to the sky" (Holbrook 2016, 1) also contributes to the science and culture intersection. Researchers like Jarita Holbrook, Johnson Urama, and Rodney Medupe have contributed to the sub-field of African Cultural Astronomy in the past decades. This work has begun to highlight significant and historical relationship to sky that includes: timekeeping, establishing calendars, navigation, fertility cycles, agriculture, medicine, art, and ceremony (Urama and Holbrook 2009). Literally hundreds of Indigenous tribes or ethnic groups inhabit the continent of Africa. As this cross-discipline of astronomy, anthropology, archaeology, and other scholars gains momentum the connection between science and culture is expected to further build common ground between academia and Indigenous communities.

In addition to the recovery and revitalization of cultural knowledge, African education scholars work to build and implement culturally based science education (Snedegar 2007). In the 1990s, African educationalist Olugbemiro Jegede and contemporaries suggested the need to recognize the social context of learning, particularly the Indigenous knowledge base of the learner, the socio-cultural background, in order to achieve learning gains (Ogawa 1995; 1986; Ogunniyi 1988; Jegede 1995; Jegede and Aikenhead 1999). Jegede states, "the culture of the learner has a central role in learning science" (1995, 97). And similarly, "Rather than subjugate the Indigenous system to a dominant Western paradigm, the educational objective should be to bring about 'collateral learning' (Jegede 1995) by which both approaches are in a real sense validated" (Snedegar 2007, 28).

Canadian First Nations, Inuit, and Metis peoples' work towards defining Indigenous knowledge and Indigenous science education has been progressing rapidly since the mid-1990s (Wilson 2003; Martin 2003). In 1996 a landmark report, "The Royal Commission Report on Aboriginal Peoples", examined the relationships between Indigenous people and the Canadian government (Dussault et al. 2016). In the 4,000-page report, urgent and sweeping changes were called for between the Indigenous and non-Indigenous communities and the government. As more Indigenous scholars entered and became successful in academia, gradually their voices became stronger, questioning and examining the foundations of science. One landmark book in shifting the climate was "Decolonizing Methodologies", written by Maori scholar, Tuhiwai Smith (1999). Later Indigenous scholars (Battiste, Bell, and Findlay 2002; Battiste 2005; Henderson 2000) gained momentum to actually define the Indigenous Research paradigm as a way of knowing parallel to the Euro-centric Anglo way of knowing, that came to be known as 'science'. Indigenous research, cultural protocols, and culturally congruent methodologies have been outlined by researchers such as Wilson (2003) and Aikenhead et al. (2010). Additional momentum was gained by a broader initiative called, the "Truth and Reconciliation Commission of Canada (TRC)" which was established in 2008 in order to document the history of the Canadian Indian residential school system and the historical trauma past and present as mandated by the Indian Residential Schools Settlement Agreement (IRSSA) (Moran 2015; May 16, June

14, and 2010 2008; "Schedule N of the Indian Residential Schools Settlement Agreement" 2006).

Indigenous scholars in Canada have made significant progress in the areas of decolonizing science and creating a blended educational model of Eurocentric and Indigenous worldviews. Efforts to dismantle "the monopoly of Eurocentric education" and getting Indigenous knowledge and curricula into the national and local classrooms have focused on sensitizing the teachers to the embedded practices that were rooted in colonialism and that continue to marginalize Indigenous students (Battiste 2005). Mi'kmaw scholar Marie Battiste argues that the most damaging result of the Western European educational system has been "cognitive imperialism". She describes this as a direct way of using the educational system to reinforce cultural norms at the expense of others. In denying the value of other cultures and languages, and allowing only one frame of reference, systematic discrimination and racism are sustained.

In 2004 two Mi'kmaw elders Murdena Marshall and Albert Marshall worked with biologist Cheryl Bartlett to address widening Native participation in science and improving science curricula at Cape Breton University (CBU) in Nova Scotia, Canada (2012). A fundamental part of their work in weaving together Indigenous knowledge (IK) and mainstream science (biology) is the principle of 'Etuaptmumk' or Two-Eyed Seeing. First introduced by elder Marshall in 2004:

> *Two-Eyed Seeing is learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of Western knowledges and ways of knowing, and to use both these eyes for the benefit of all.* (Bartlett, Marshall, and Marshall 2012, 336)

Researcher Glen Aikenhead of the Aboriginal Education Research Centre in the College of Education of the University of Saskatchewan, in collaboration with the Saskatchewan Ministry of Education, has done extensive work on recognizing Indigenous knowledge as a fundamental part of understanding the physical world and then working to embed their new curriculum into the regions K-12 schools. This updated curriculum includes place-based, culturally responsive science lessons (Aikenhead and Elliott 2010) along with teacher training and resources. Aikenhead provides a three-step approach to achieving 'ethno-pluralism' or cross-cultural school science: acceptance, adaptation, and integration. He argues that cultural diversity is as critical to humanity's survival as biodiversity is critical to the world's global biome (Aikenhead and Elliott 2010).

Cultural astronomy and Indigenous Astronomy revitalization efforts in Canada include prodigious work done by Wilfred Buck, Ininew elder and science educator. He offers insight on the value of native perspectives in the educational system:

> *We as individuals tend to view our civilization as "the best" and when our teachings, knowledge, and belief systems are ridiculed, marginalized and then utterly dismissed as "quaint", we begin to question our world view. This has happened and is still happening to First Nations people as well as all colonized peoples. Until other world views are proposed and considered, there will be a distinct "difference" and "quaintness" about all that is not mainstream. In addition, our children will see these differences and attempt to discard them in*

order to become more mainstream. These teachings reflect the differences and propose another perspective, broadening and giving voice to them...The implications for the educational systems (public schools and federally funded Band operated schools) in which are children are indoctrinated, is that it recognizes the "otherness", and becomes a part of our multicultural nation. (Buck 2012, 73)

Another example of significant progress is the "Science First Peoples Teacher Resource Guide" (Campbell et al. 2016) published by the First Nations Education Steering Committed and First Nations Schools Association in West Vancouver, British Colombia, Canada. In over 200 pages, eight sections of guidance and eight classroom ready units are shared. Key points of this Indigenous pedagogy for grades 5-9 include: learner centered; inquiry based; experiential learning based; awareness of self and other in equal measure; recognize the value of group processes; variety of learning styles (Campbell et al. 2016). Content of the units consists of themed topics such as: "Plants and the Connection to Place", "Bears and the Body Systems", "Climate Change", and "Interconnectedness of the Spheres". Pedagogical sections include topics such as: "First Peoples Pedagogy", "Making Connections with the Community", "Suggestions for Developing Locally-Based Resources", and "Assessment". Three different approaches to science are explained: Indigenous knowledge; Contemporary Science, and School Science.

Indigenous Knowledge is the knowledge of Indigenous peoples, including scientific and evidence-based knowledge, that has been built up over thousands of years of interaction with the environment. It is holistic knowledge rooted in place and contained in language.

Contemporary Science is an evidence-based way of understanding the natural world. Asking questions and discovering answers results in a continuous revision of knowledge. Scientific knowledge is provisional and influenced by culture, beliefs and ethics.

School Science encompasses both what is considered important to teach and learn in K-12 schools, and how science is taught. Ideally, it incorporates scientific curiosity and inquiry. (Campbell et al. 2016, 6-7)

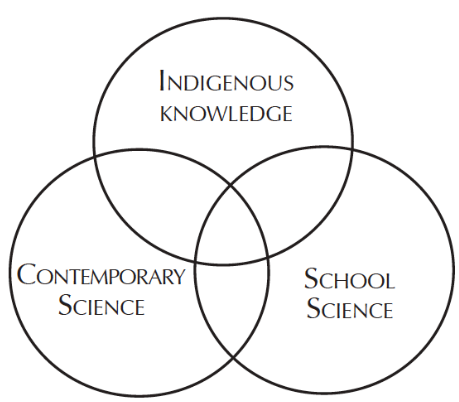


Figure 9 - Three approaches to science (Campbell et al. 2016, 7)

Teachers are encouraged to create and foster classroom environments at the places of convergence, that "substantiate the interconnectedness of all things" and when necessary "some school science has been left behind by not being part of the convergence" (Campbell et al. 2016, 7).

Indigenous scholars in Australia since the 1990s have dissected race and racism as a social construct and a weapon of Western science used to allocate power (Bin-Sallik 1990; Rigney 2001). This link between science and access to power is described here, "Race theories laid the firm foundation for determining whose knowledge was valid and whose science was legitimate. More importantly, they determined who could do science and who could be a scientist" (Rigney 2001, 4). According to Wilson (2003) three government initiatives helped to ignite this work of Indigenous research by Indigenous researchers: (1) Council for the Aboriginal Reconciliation Act (1991); (2) Royal commission into Aboriginal Deaths in Custody (1991); (3) National Inquiry into the Separation of Aboriginal and Torres Strait Islander Children (1996). As Western science positioned itself as 'rational and universal' it discredited other ways of knowledge production and investigation. The historical context of inequities for Australian Aboriginal people is shocking. Fortunately in 1967 Indigenous Australians were first recognized as citizens of their own country and first included in the census. In 1985 the National Aboriginal Educational Committee (NAEC) was able to support participation of Indigenous peoples in higher education. In 1999 the report titled, "Research of Interest to Aboriginal and Torres Strait Islander Peoples", credits Indigenous scholars for critiquing Western science and the historical roots of race and colonialism (Australian Research Council 1999).

Indigenous scholars such as Martin Nakata (2002) address the notion of 'cultural interface':

> *Knowledge systems are culturally embedded, dynamic, respond to changing circumstances and constantly evolve. It is not strictly about the replacement of one with the other, nor the undermining of one by the other. It is about maintaining the continuity of one when having to harness another and working the interaction in ways that serves Indigenous interests.* (Nakata 2002, 286)

In addition, Indigenous scientist, Rowena Ball, specifically remarks:

> *Indigenous astronomy is a particularly rich body of knowledge because it has additional precious functions: the night sky encodes cultural practices, laws, histories and ground-based songlines. It is a tradition of which we all should be proud nationally, and if it could be woven into the national school curriculum, Australian children would grow up with and respect and propagate this precious knowledge, and it would help to shape and distinguish our national identity.* (Ball 2015, 15)

Astronomers and ethnoastronomers in Australia such as Ray Norris, Duane Hamacher, and Ragbir Bhathal (Hamacher and Norris 2011; Hamacher 2012; Bhathal 2006; Clarke 1997; Johnson 1998; Norris and Norris 2009) have been working towards acknowledging, recovering, and disseminating the Australian Aboriginal living connection with the night sky that predates colonialism by at least 50,000 years (Hamacher and Norris 2011). The density of the Aboriginal observations and knowledge of sky included: time-keeping, seasonal change, navigation, food economics, tidal prediction, as well as ceremonies and rituals. Observations of stellar variability, astronomical measurements, stone alignments, and complex motions of celestials objects were all included in Aboriginal peoples' participation in celestial phenomena (Hamacher and Norris 2011).

2.2 Native Science in the U.S.

The historical context of government imposed American Indian education in the United States reveals the continued forces of colonialism. Education was used as a means to assimilate. Education was a means to force the assimilation of children into the broader American culture at the expense of abandoning their own Indigenous culture. This was done through brutal campaigns of forced removals, massacres, boarding schools, and land allotment. All of this was justified by manifest destiny, the moral basis to 'Kill the Indian, save the man' (Nuby 2014; W. Young 2014; Reyhner 2014). Education was "an attempt to wash the 'savage habits' and 'tribal ethic' out of a child's mind and substitute a white middle-class value system in its place" (U.S. Congress 1969, 9). Two primary methods of assimilation were teaching Anglo farming and imparting Christianity (Klug 2014). After decades of damage, in 1969 a groundbreaking report known as the "Kennedy Report", spelled out the inequities in Indian Education (U.S. Congress 1969) and paved the path for the Indian Self-Determination and Education Assistance Act of 1975 which gave tribes the power to lead their own education and health systems.

About the same time, scholars of the 1970s built critical race theory which began to examine the institutional racism embedded in mainstream U.S. society allowing the privileged class to remain in power and reinforcing the existing social order. Near the turn of the millennium Indigenous scholars, created a branch of critical race theory that specifically focused on Native inequities, Tribal Critical Race Theory (TribCrit) (Brayboy 2005; Writer 2002; Rains 2003; Williams 1997).

Although various perspectives exist, one description of the difference between Western science and Native science is as follows:

> *Indigenous science… is 'full-spectrum science'. It draws freely on all four of the gifts that have been given to us as human beings: the spiritual, emotional, mental, and physical. By contrast, Western science dwells mostly on the physical and mental, often rejecting the spiritual and feeling or emotional qualities of life with great arrogance and finality.* (Simonelli 1994, 37)

One of the leading voices of Native science, Gregory Cajete states, "Native science is born of a lived and storied participation with the natural landscape. To gain a sense of Native science one must participate with the natural world" (Cajete 2000, 2). Two of the fundamental views of science using the Native cultural lens are: relationship and participation. Indigenous scholar, Shawn Wilson further emphasizes this point saying that, "Reality is not an object but a process of relationships….Relationships are fundamental to the Indigenous way of living and working in the world…the relationship with something (a person, object or idea) is more important than the thing itself" (Wilson 2008, 73).

The Native American worldview includes the fundamental ideas that: (1) all things are made of energy, "In Aboriginal philosophy, existence consists of energy. All things are animate, imbued with spirit, and in constant motion" (Little Bear 2000, 77); (2) we are all related, "In this realm of energy and spirit, interrelationships between all entities are of paramount importance…" (Little Bear 2000, 77); (3) in the search for knowledge and truth, the Universe is dynamic and all things are not knowable, "Nature will always possess unfathomable mysteries" (Kawagley and Barnhardt 1998, 4). This is in contrast with the Western science worldview: spirituality is centered on a single supreme being; humans exercise dominion over nature to use it for personal and economic gain; human reason transcends the natural world and can produce insights independently; nature is completely decipherable to the rational human mind (Knudtson and Suzuki 1992). As Carter et al. (2003) note, "The emphasis of Western science is on mastering, controlling, and transforming nature and promotes individual success and competition" (p. 6).

Another example that highlighted the differences between 'mainstream' education and Native education in the U.S. was the results of a qualitative study in which 60 teachers of American Indian students were interviewed over three years. One significant result found was a difference in the learning styles of American Indian students as compared to frequently used teaching styles in mainstream schools. Specifically the Native learning, cultural, and motivational styles identified were: (1) teaching to a variety of learning styles; (2) the influence of culture on learning; (3) the need for competence; (4) cooperative rather than competitive; (5) visual learning; (6) oral learning; (7) need for personal and practical applications; and (8) wholistic learning (Cleary and Peacock 1998, 154-162). The interviewed teachers agreed there was no single learning style of Native students, but that good teachers use multiple methods adjusted to the need and preferences of their learners. Realistic differences in behavior were pointed out. For example, in Native culture it is a sign of respect to not look a person directly in the eye, especially an elder. A non-Native teacher explained this situation, "I didn't understand what was going on. If you watch very traditional people talk, they never look at each other, but everyone listens to what everyone says" (Cleary and Peacock 1998, 29). Further cultural differences were found in: perception of time, use of humor, language revitalization, designation of family, and spirituality.

Other scholars, such as Angayuqaq Kawagley and Ray Barnhardt, working with elders from the Yup'ik tribe wanted to find a common ground with Western science suggesting that Native Alaskan students should learn Western science alongside of the traditional knowledge, and that Indigenous knowledge offers the contribution of many generations of observations, "breadth to the scientists' depth" (1998, 13). They found that long-term perspective, interconnectedness, adaptation, and commitment to the larger group were the key differences in the Yup'ik elders' worldviews. Multiple studies of science education for Native students show the importance of collaborative learning, hands-on learning, connecting science to other subjects, and especially to the land (Rowland and Adkins 2003).

In a national report, "The Common Core Initiative, Education Outcomes, and American Indian/Alaska Native Students" (Nelson-Barber and Trumbull 2015), the following short list of key values were outlined as differences between American Indian/Alaskan Native (AI/AN) culture and a dominant culture worldview:

> *Spirituality-An appreciation for spiritual relationships is inherent in all education endeavors; Service-The purpose of education is to contribute to the well-being of the people; Diversity-Indian education must meet the standards of diverse tribes and communities; and Culture-Indian education must recognize the importance of*

> *and be guided by culturally determined ways of thinking, communicating, and living.* (Nelson-Barber and Trumbull 2015, 23)

2.3 Modern Scientific Knowledge Systems

The etymology of the word 'science' shows a significant narrowing in the definition of science since the 14th century. Originally from the Latin word 'scientia', the initial definition of science was rooted in a much broader idea of the pursuit of knowledge: "Knowledge or understanding acquired by study; acquaintance with or mastery of any branch of learning" (Oxford English Dictionary 2019b). "The state or fact of knowing; knowledge or cognizance of something; knowledge as a personal attribute" (Oxford English Dictionary 2019b). Today, science is defined:

> *A branch of study that deals with a connected body of demonstrated truths or with observed facts systematically classified and more or less comprehended by general laws, and incorporating trustworthy methods (now esp. those involving the scientific method and which incorporate falsifiable hypotheses) for the discovery of new truth in its own domain.* (Oxford English Dictionary 2019b)

The term 'modern science' has only been in wide-spread use since the beginning of the 20th century (Snively and Corsiglia 1998). In a similar way, the word 'physics' comes from the Latin word 'physica' meaning *"natural things"* (Oxford English Dictionary 2019a) or Natural Philosophy. From 1723, "This Word, 'Physicks', strictly speaking, and according to the etymology of it, signifies no more than 'Natural'" (Oxford English Dictionary 2019a). Likewise physics is currently defined as:

> *The branch of science concerned with the nature and properties of non-living matter and energy, in so far as they are not dealt with by chemistry or biology; the science whose subject matter includes mechanics, heat, light and other radiation, sound, electricity, magnetism, gravity, the structure of atoms, the nature of subatomic particles, and the fundamental laws of the material universe.* (Oxford English Dictionary 2019a)

From the philosophy of nature to a mechanistic Cartesian model, significant changes in the definitions of words like 'science' and 'physics' are clearly evident in the historical record.

It is commonly written in introductory physics and astronomy textbooks that Western science was founded on the 'shoulders of giants' or 'the fathers of science'. Men like Galileo (1564-1642), Isaac Newton (1643-1727), Tycho Brahe (1546-1601), and Einstein (1879-1955) are held up as champions of the scientific method, expert practitioners of measurement, mathematics, data collection, and prediction. Indeed the scientific method is laid out in a flow chart as: observation, measurement, prediction, falsification, theory. The cosmological principle and the strategy of divide and conquer are pillars of modern science practice and education.

What became known as the scientific worldview or epistemology was inspired by the "Century of Philosophy" (1715-1789), or the European Enlightenment, which quickly led to the separation of man and nature. Nature became a social construct as stated here, "Modernity's impression of itself as the expression of universal truth has led to a science and philosophy, particularly since the earliest days of the Enlightenment, which seeks to remove 'man' from nature and the 'savage' non-European masses from civilized Europe" (Johnson and Murton 2007, 122). Colonial expansion and manifest destiny served to advance this concept of the European civilized man "constructed as the disembodied and distanced observer, with the exclusive privilege and the extraordinary power to discover the real order of the world" (Johnson and Murton 2007, 122). Modern science came from a branch of Western European culture, and as much as science aims to be objective and universal, it is embedded with a Western European worldview, yet significant parts of what is called "Western science" were borrowed from Middle East and Asian cultures. For example, the sexagesimal base 60 number system dates back to the Sumerians in 3000 BC, and was then passed on to the Babylonians, present day Iraq (Ifrah 1999). "It is now quite certain that a very considerable amount of the astronomical knowledge used, analyzed, and to some extent better interpreted by the Greeks, was taken from the Babylonians" (Clarke 1962, 70). Adding to the point, Joseph Needham explains, "Surely it would be better to admit that men of the Asian cultures also helped to lay the foundations of mathematics and all the sciences in their medieval forms, and hence to set the stage for the decisive break-through which came about in … the Renaissance" (1993, 45).

2.4 Summary of Relevant Concepts

Since the 14th century the meaning of science has undergone dramatic transformations. Science has gone from meaning 'mastery of learning' to 'measuring falsifiable truths'. The shift in defining physics is even more dramatic, from the 'philosophy of nature' to 'fundamental laws of the material universe'. Seeing these evolving descriptions brings to light the idea that the definitions of today come with a historical footprint. When we examine that history and the culture that is embedded in the words, the bias becomes clearer. Indeed, science is not free from culture, but contains layers of "cultural fingerprints" (Le Grange 2007, 586). Mainstream science is rooted in Western European culture. Since the 1990s there is a growing global sense of re-examining and re-defining science so that multiple world-views are included.

Science education has followed this Eurocentric trend entrenching teachers and students with this conceptualization of science as the search for knowledge and truth, using premises of objectivity and the scientific method (Carter 2011). Scholars who work in the area of multicultural science education have examined what parts of science were shaped by colonial Eurocentric worldviews, and how science might consider re-defining itself in a postmodern society where increasingly ethnically diverse classrooms are quickly becoming the norm (Rowland and Adkins 2003). Research in education such as, "Who's Asking" (Medin and Bang 2014b), provide an analysis of science and science education and conclude that the scientific method is idealistic and overly optimistic. They go on to argue that science is embedded with values as defined by culture, race, gender, and socioeconomic status.

As has been pointed out "science communication necessarily involves cultural orientations" (Medin and Bang 2014b, 13621) and "it would be a serious error to make the inference that scientists shed their own cultures when they enter through the doors of science" (Medin and Bang 2014b; 2014a, 13622). Indeed one of key perspectives that differs by culture is the "psychological distance between humans and the rest of nature" (Medin and Bang 2014a, 13621). Cajete goes even further to recognize the Western worldview as a "dysfunctional cosmology, a cosmology that can no longer sustain us at any level" (Cajete 2000, 53). Ultimately

Cajete proposes that Western science needs Native science to recalibrate its prevailing worldview and culture which is based on individualism and capitalism. Described in more detail:

> *Western science has often been caught up in an almost fanatic drive to objectify and fragment all of human experience so that it could somehow be better or more clearly understood or controlled. But these methodologies often forget to recontextualize data bits, or to recycle that knowledge into a meaningful expression for human life and human situations. Indigenous science is a process of thinking and relating that refuses to decontextualize.* (Cajete 2000, 307)

In summary, this chapter examines the cultural assumptions and approaches embedded in science. There is a recognition that what has been referred to as 'science' is really only one way of knowing the natural world that has clearly evolved from one cultural perspective, Western European culture. In addition and critically important, there is growing momentum, acknowledgement, and inclusion of Indigenous knowledge systems of science in countries around the world.

This purpose of this research project was to design concrete ways in which non-Western European instructional materials and strategies, informed by Indigenous knowledge systems (IKS), could be embedded in a college level introductory science course, Astronomy 101. As stated by UNESCO (2003), Jegede of South Africa (1995), and First Nation Mi'kmaw elders of Canada (2004), the goal is to do both. As Kawagley and Barnhardt (1998) keenly pointed out Indigenous knowledge adds the breath to the depth of Western science. And yet, as Campbell et al. (2016) points out, some content has been left behind by not being part of the convergence. Consequently in this study, the effects of the broader content and approach needed to be measured in terms of learning gain and student engagement using a uniquely designed multi-layered, quantitative and qualitative research design, implementation, and analysis.

Chapter Three: Theoretical Frameworks

In addition to the relevance of Indigenous knowledge systems (IKS), this chapter presents the two other theories that frame the overriding research of this study, active learning theory and culturally responsive pedagogy theory. Brief overviews of the historical development of the theories are given along with important practices that are relevant to this study. This description, although concise, is intended to offer the reader a theoretical picture that is useful to build a greater understanding of the various discussions, challenges, and issues in STEM higher education. The additional two theories that best clarify and elaborate on the research of this study and the interconnected relationship with the key ideas, the research questions, and the findings are: active learning theory and culturally responsive pedagogy theory.

3.1 Active Learning in Higher Education: Theory and Practice

The origins of the university can be traced back to Middle Ages in Western Europe where the first official university was established in 1088, the University of Bologna in Italy. Later the University of Paris and the University of Oxford were established in 1150 and 1167 respectively (Brockliss 1996). The origin of the word university comes from the Latin word, 'universitas' which means "body of masters and scholars of an academic institution" ("University, n." 2019). One of the oldest traditions of learning in higher education is the lecture. Derived from the Latin word, 'lectura' which comes from the word 'legere' meaning to read and the suffix 'ure' denoting 'action or process' ("-ure, Suffix1" 2019). Lecture is the action of reading aloud. This standard method of college classroom teaching dates back to the Western European culture from the Middle Ages before the printing press when mass production of learning was not possible. At first glance this method of delivery seems to be a very efficient and direct way of communicating information yet in 1978 a study involving over 1000 medical school students from 12 lectures, showed the maximum period of concentration was reached after 10 to 15 minutes of lecture, and then declined steadily. This study suggested that the optimal lecture length should be no more than 30 minutes (Stuart and Rutherford 1978).

3.1.1 Active Learning in Higher Education

Since the 1980s, a growing body of evidence from leaders in higher education has shown lectures to be less effective than active learning (Chickering and Gamson 1987; Anderson and Adams 1992; Bonwell and Eison 1991). Researchers have increasingly urged faculty to transition from lecture based instructional methods to active learning based instructional methods. At the same time national reports (Mortimer et al. 1984; Boyer 1987; Johnson, Johnson, and Smith 1991) on post-secondary education concurred with these results and urged faculty to use cooperative learning, increase student involvement, and active learning. In a 1984 U.S. Department of Education report, "Involvement in Learning: Realizing the Potential of American Higher Education" (Mortimer et al. 1984), recommendations are specifically stated to increase student involvement, "Faculty should make greater use of active modes of teaching and require that students take greater responsibility for their learning" (Mortimer et al. 1984, 27). One seminal report, "Active Learning: Creating Excitement in the Classroom" (Bonwell and Eison 1991), addressed this call to change and its barriers. First, active learning was defined as:

> *...students must do more than just listen: They must read, write, discuss, or be engaged in solving problems. Most important, to be actively involved students*

> *must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation. Within this context, it is proposed that strategies promoting active learning be defined as instructional activities involving students in doing things and thinking about what they are doing.* (Bonwell and Eison 1991, iii)

Charles Bonwell and Tracey Sutherland (1996) went on to suggest a broad spectrum of active learning activities on the 'active learning continuum' from simple tasks such as pausing three times during a 50-minute lecture to increase learning, (Ruhl, Hughes, and Schloss 1987) to complex tasks such as the 'jigsaw strategy' where students work in small groups, learn a new concept then remix to teach their peers, (Johnson, Johnson, and Smith 1991). Characteristics of active learning are spelled out: (Bonwell and Eison 1991, 2):

- Students are involved in more than listening.
- Less emphasis is placed on transmitting information and more on developing students' skills.
- Students are involved in higher-order thinking (analysis, synthesis, evaluation).
- Students are engaged in activities (e.g., reading, discussion, writing)
- Greater emphasis is placed on students' exploration of their own attitudes and values.

Active learning theory grew out of constructivist theory which emphasizes that learning is a process where students learn best by building knowledge or connecting old knowledge with the new knowledge. This theory was developed in the 1920s by Swiss psychologist Jean Piaget et al. through cognitive studies of how infants learn (Bransford, Brown, and Cocking 2000). It was previously thought that babies were incapable of complex thought. Studies showed that infants were indeed capable of complex thinking involving: causality, numbers, and language. Learners can blend new knowledge into existing frameworks or update a framework to accommodate the new knowledge. In other words, human beings construct knowledge from their experiences. Active learning approaches challenge the learner to participate real-time in constructing knowledge. This was directly opposite of the 900-year-old tradition of the most common classroom delivery, lecture, where students are passively listening.

Some early active-learning research focused on the idea of course structure and the impact that it has on the students' learning experience and faculty reluctance to change (Miller, Groccia, and Wilkes 1996). Different students have different cognitive styles and come into a course with different stages of cognitive development based on their prior experiences. In order for a faculty to design and deliver a successful course, the idea of course structure must be considered (Miller, Groccia, and Wilkes 1996). If active learning was going to replace lecture, or even simply supplement lecture, faculty needed to take action.

Another important idea in the shift towards a more student-centered classroom environment is cooperative learning versus the traditional competitive classroom learning. There are different types of cooperative learning groups, informal short-term to formal and long-term. Karl Smith (1996) describes the five essential components of a well-structured cooperative learning group: positive interdependence, face-to-face promotive interaction, individual accountability/personal responsibility, teamwork skills, and group processing. The strength of the collaborative learning experience is that students have the opportunity to actively relate to each other personally and academically.

> *Student participation, teacher encouragement, and student-student interaction positively relate to improved critical thinking. These three activities confirm other research and theory stressing the importance of active practice, motivation, and feedback in thinking skills as well as other skills. This confirms that discussions… are superior to lecture in improving thinking and problem solving.* (McKeachie et al. 1986, 19)

Research led by Vincent Tinto at Syracuse University showed that active learning was linked to college retention:

> *…the most important condition that fosters student retention is learning...Active involvement seems to be the key. Students who are actively involved in learning activities and spend more time on task…are more likely to learn, and in turn, more likely to stay…Unfortunately, most first-year students experience education as isolated learners. They engage in solo performances and demonstrations in what remains a largely show and tell learning environment. Their experiences of learning are still very much like a spectator sport in which faculty talk dominates and where few students actively participate.* (Tinto 1999, 6)

The two biggest reasons for college departure were found to be: social alienation and failure to be involved in classes (Tinto and Russo 1994). A later study led by John Braxton et al. (2000) surveyed over 700 first year students at a research university. Four composite measures were used to code active learning: class discussion, activities, exams (focused on facts), and group work. Class discussions and activities (higher order thinking activities) were shown to influence social integration. Furthermore, class discussion was positively correlated to institutional commitment, and fact-based exams were negatively correlated to institutional commitment (Braxton, Milem, and Sullivan 2000). In other words, discussions and activities helped students feel a greater sense of community in the classroom. Even better, discussions enabled students to feel a greater sense of large-scale accountability, especially compared to learning by memorization which had the opposite effect in students. A 2008 study that included a wider range of colleges again supported the link between active learning and student retention of first-year college students. Recommendations were made for increased faculty professional development, recognition of active learning as part of the tenure and promotion practice, advisors to direct students to courses where faculty practice active learning, and student course ratings should be linked to use of active learning (Braxton et al. 2008).

3.1.2 Active Learning in STEM Higher Education

A few ground-breaking studies in STEM have provided robust analysis of learning gains for courses using active learning approaches. In 1997 Eric Mazur published "Understanding or memorization: Are we teaching the right thing?" (Mazur 1997b) and in that same year a user's manual for teaching using an active learning approach called Peer Instruction (PI) (Mazur

1997a). Originally developed for teaching introductory physics, the approach focuses on the concepts underlying the more difficult calculation-based problems. Mazur had discovered that many students could actually solve difficult quantitative problems but their understanding of the underlying physics was weak. A typical Peer Instruction (PI) class replaces the lecture with short, ten minute, lectures that focus on three or four key points. Between each mini-lecture are a few carefully designed multiple-choice conceptual questions, called ConcepTest, that student work on individually and then with their peers. Students’ doubled their gain in understanding on the Force Concept Inventory (Hestenes, Wells, and Swackhamer 1992) and the Mechanics Baseline Test (Halloun and Hestenes 1985) improved dramatically. In addition, students’ quantitative problem solving abilities was strengthened and overall class satisfaction increased (Mazur 2009). Since then PI has been applied in various universities around the world and in many disciplines such as: math, biology, computer science, engineering, and medicine (Passeri and Mazur 2019).

A landmark study was done by Richard Hake (1998). Over 6000 students enrolled in an introductory physics course were involved either in a ‘traditionally’ (T) taught course, which was lecture-based and contained no active learning; or an ‘interactive-engagement’ (IE) course, which implemented active learning. Learning gains were measured using the physics concept inventory exams, Mechanics Diagnostic Test or the Force Concept Inventory. Hake found that students in the interactive engagement (IE) course experienced an average normalized gain of 0.48 ± 0.14, as compared to students in the traditional (T) course whose average normalized gain was 0.23 ± 0.04. The study concluded:

> *Comparison of IE and traditional courses implies that IE methods enhance problem-solving ability. The conceptual and problem solving test results strongly suggest that the use of IE strategies can increase mechanics-course effectiveness well beyond that obtained with traditional methods.* (Hake 1998, 18)

Hake also adds that the interactive engagement methods used in the IE physics classroom were all products of physics education research (PER) and cognitive science research. In addition, of the 12 IE courses that students received outstanding gains (defined by gains greater than 0.60), 67% of these IE courses were taught by individuals involved in and publish in PER (Hake 1998). He goes on to endorse PER as producing “very positive results in the classroom”, and urges other physics teachers to implement IE teaching strategies (Hake 1998, 18).

Around that same time, Leonard Springer et al. (1999) completed a meta-analysis of studies that involved cooperative small group learning across all science, mathematics, engineering, and technology (SMET) disciplines. Note that prior to 2001, SMET was the acronym for what is currently referred to as STEM, both acronyms were introduced by the National Science Foundation (NSF) for the disciplines of science, technology, engineering, and math (Hallinen 2019). The meta-analysis results found that small group learning produced higher learning gains as compared to student in a traditional lecture-based course. In addition to test scores, variables such as ‘student attitudes’ and ‘student persistence’ were shown to increase in the courses that included active learning in the form of small group learning. Springer et al. called for “instructional innovation in undergraduate science courses” and “a need for a solid foundation of education research at the undergraduate level on which to base policy and practice” (Springer, Stanne, and Donovan 1999, 21).

Another large-scale study on active engagement was published by Tierra Freeman et al. (2014). After meta-analyzing 225 studies of student performance in STEM, using traditional lecture or active learning, it was found that average student performance on exams and concept inventories was higher by 0.47 SD for active learning courses (Freeman et al. 2014). In addition, the results indicated that students in a traditional lecture-based course had a 33.8% average failure rate as compared to students in the active learning course had a failure rate of only 21.8%, which represents a decrease in failure rates by 55% in the active learning course. To summarize this work:

> *This is the largest and most comprehensive meta-analysis of undergraduate STEM education published to date. The results raise question about the continued use of traditional lecturing as a control in research studies, and support active learning as the preferred, empirically validated teaching practice in regular classrooms.* (Freeman et al. 2014, 8410)

These results were valid across all STEM disciplines, in introductory and upper-division courses, and in all course sizes, although the highest impact was seen on courses with 50 students or less (Freeman et al. 2014).

On a smaller scale, Jennifer Knight and William Wood (2005) showed that in an upper division developmental biology course "significantly higher learning gains and better conceptual understanding" were produced in the more interactive course. Specifically, the intervention included: decreased lecture time replaced with cooperative problem solving in class, frequent in class assessment of understanding using clickers, and more student responsibility to learn outside of class. Interestingly, the results also indicated that some students were apprehensive about the alternative course format, "Although many students in the S'04 and S'05 courses at first disliked and distrusted the interactive classes and group activities, most became comfortable with the unfamiliar format and ultimately reported that it helped their learning" (Knight and Wood 2005, 304).

The following table illustrates published examples of active learning exercises (Handelsman, Miller, and Pfund 2007; Felder and Brent 2009; Handelsman 2004):

Table 1 - Published Examples of Active Learning Exercises

Active Learning Activity:	Published References:
Group Problem Solving	Meyers and Jones 1993; Dolmans et. al. 2001; Spring, Stanne, and Donovan 1999
Electronic audience response system (Clickers)	Wood 2004; Poirier & Feldman 2007
Brainstorming	Hsieh et. al. 2011; Zayapragassaranzan and Kumar 2012
One-minute questions	Harwood 1996; Stead 2005
Strip sequence	Armbruster et.al. 2009
Decision making	Grabinger and Dunlap 2016; Richards et. al. 1995
Concept maps	(Cornell Univ.) 1972; Novak and Canas 2006; Hsu 2004; Charsky and Ressler 2010
Case and problem-based learning	Allen and Duch 1998; Duch et. al 2001; Waterman and Stanley 2005
Think-Pair Share	Millis, Lyman & Davidson 1995

ConcepTests	Mazur 1997; Boller 1999

In additional to disseminating curriculum and pedagogy, one widely-used approach to shift STEM classrooms from the lecture-based, content focus to a more student-engaged format is through the use of professional development for faculty (Freeman et al. 2014; Singer and Smith 2013; Derting et al. 2016). Not surprisingly, it has been found that "adoption of teaching practices that have been demonstrated to improve student learning is more frequently associated with instructors who invested more in learning about teaching" (Manduca et al. 2017, 7). In a large analytical review of literature on STEM instructional practices conducted by Henderson et.al the most effective change strategies were found to be: (1) changing faculty conceptions, (2) long-term interventions, and (3) understanding the complexities of the higher education (Henderson, Beach, and Finkelstein 2011).

From a STEM faculty point of view, barriers to change were found to be: lack of recognition and rewards, lack of time, and lack of support (Henderson, Beach, and Finkelstein 2011). Susan Shadle et al. (2017) published study of 169 STEM faculty at a Midwest regional comprehensive university found the most frequently faculty identified barriers as: time constraints, instructional challenges, loss of autonomy, and resistance to change. According to a study done by Lorelei Patrick et al. (2016) in a survey of STEM faculty and students it was found that perceptions varied by discipline: geology had the highest use of active learning and mathematics the least. Interestingly, about 75% of students and faculty agreed that a barrier to implementing active learning was 'have become accustomed to lecture-based methods', about 60% pointed to 'not enough class time to use active learning', and nearly 50% of students and faculty stated agreement with 'Do not feel that active learning is a productive use of class time'.

In spite of the well-established benefits of active learning, students themselves are not necessarily convinced (Seidel and Tanner 2013). A study by Andrew Cavanagh et al. (2016) examined the extent which students: were exposed to active learning, persuaded that the activities were beneficial, identified active learning as their preferred way of learning, and committed to engaging in active learning. 'Buy-in' was defined as "an individual's feelings in relation to a new way of thinking or behaving" (Cavanagh et al. 2016, 2). The intention of the study was better understanding the nature of student buy-in within active learning classrooms and to what extent engagement is associated with buy-in. It was found that student buy-in was not uniform, some students believed in active learning, others were unconvinced. A 'multiphase process' of student buy-in was recommended (Cavanagh et al. 2016, 6). Apparently, the question of how students become engaged is relatively unstudied.

3.1.3 Active Learning in STEM Higher Education and Inclusion

The studies reviewed above have demonstrated how active learning leads to increased student performance and learning gains across all disciplines (Michael, 2006). In addition, there is increasing evidence that active learning approaches are an effective way to create more inclusive classrooms. In a broad sense, various interventions have been implemented and shown to address the achievement gap between underrepresented (URM) ethnic minority students and majority students (Rath et al. 2007; Treisman 1992; Haak et al. 2011; Preszler 2009; Eddy and Hogan 2014). These include interventions such as mentoring, supplemental instruction, studio-style classes, undergraduate research opportunities and support groups. Lisa Tsui (2007) published a summary of ten evidence-based successful intervention strategies as follows: summer bridge programs, mentoring, research experience, tutoring, career counseling, learning centers, workshops and seminars, academic advising, financial support, and curriculum and instruction reform. Three model intervention programs were also identified as exemplary: the Meyerhoff Program, the Minority Engineering Program (MEP), and the Mathematics Workshop (Tsui 2007). Some of these interventions are reviewed in the section below.

A type of workshop to successfully address the achievement gap was pioneered by Uri Treisman in the 1990s. These supplemental instruction models were peer-led outside of class workshops, which provided a sense of community while at the same time promoted skills especially in introductory STEM courses with high failure rates, such as freshman calculus (Treisman 1992; Cullinane and Treisman 2010; Fullilove and Treisman 1990). The Treisman model was built from previous research on Asian students' study habits. It was found that Chinese American students "organized themselves into informal study groups which provided them with an efficient means to accomplish a variety of tasks that are vital for survival at UCB" (Fullilove and Treisman 1990, 466). Students enrolled in the Treisman honors workshop were first-year students of whom 80% were African American or Hispanic. Results found that students enrolled in the workshops were two to three times more likely to earn a grade of B- or better than non-workshop students (Fullilove and Treisman 1990). The workshops created peer learning groups who became intent on maintaining their success and acquired a strong connection to community (Fullilove and Treisman 1990). This well-known intervention program became known as the Mathematics Workshop Program (MWP) and alternatively the Professional Development Program (PDP).

In the early 2000s other programs successfully created learning environments to promote active, collaborative-based learning. The SCALE-UP (Student-Centered Activities for Large Enrollment Undergraduate Programs) project created by Robert Beichner et al. at North Carolina State University replaced the lecture-lab traditional course format with a studio style activity-based format for physics and later for other STEM courses (Beichner and Saul 2003; Gaffney et al. 2008). Typically, SCALE-UP class time is hands-on and interactive, students work in teams of three, in a computer-rich environment, addressing difficult problems or simulations. Instructors circulate around the room engaging students in Socratic-like dialog. Results indicate that, "Ability to solve problems is improved, conceptual understanding is increased, attitudes are improved, failure rates are drastically reduced (especially for women and minorities)…" (Beichner and Saul 2003, 1). Overall students enrolled in a SCALE-UP section were three times less likely to fail the course as compared to a student enrolled in a traditionally taught section. Although originally developed for large lecture physics courses, the SCALE-UP model has been disseminated across the U.S. and employed in both STEM and non-STEM courses (Gaffney et al. 2008). The project also emphasizes the development and dissemination of new active learning teaching materials and the co-teaching model (Beichner et al. 2007).

Another example of a comprehensive intervention program is The Meyerhoff Scholars Program started in 1988 at the University of Maryland Baltimore County (UMBC). Here is an exemplary model of an undergraduate program that involves scholarships, mentoring, and workshops particularly for African American undergraduates pursuing STEM. The Meyerhoff Program uses the following targeted strategies: knowledge and skills; motivation and support; monitoring and advising; and academic and social integration (Tsui 20017) to create a supportive community environment that extends beyond the classroom. Students enrolled in the Meyerhoff program were twice as likely to earn a STEM undergraduate degree and over five times more likely to attend graduate school (Maton and Hrabowski III 2004).

Since 1999, Kenneth Rath et al. (2007) at San Francisco State University have been implementing supplemental instruction (SI) for introductory biology courses. Originally developed by Deanna Martin at the University of Missouri-Kansas City (Burmeister and Martin 1996), this model uses cooperative learning to support difficult large lecture classes and improve retention. These 'gateway' or 'gatekeeper' courses often have a failure rate of 30% or higher. Examples of teaching strategies include: discussions, exploring misconceptions, visual modeling of problems, practice tests, and trivia games. SI participants (1999-2005) had higher pass rates, higher final grades, and higher graduation rates than non-SI participants (Rath et al. 2007). Gains were found to be much greater for URM students that participated in SI as compared to non-URM students, "26 (URM SI) students achieved grades allowing them to pursue majors in the biological sciences, when had they not take SI, one would have predicted that they would not have been able to pursue these majors" (Rath et al. 2007, 213). "Supplemental instruction (SI) arranged as a separate class or through a web interface has proven to be an effective method for enhancing learning in biology, particularly for underrepresented groups" (Dirks 2011, 7).

Despite the definite success of these type of programs to widen participation in the sciences and thus lower the achievement gap between ethnically underrepresented (URM) students and majority students, often these types of initiatives were expensive and not sustainable once funding expires (Preszler 2009; Haak et al. 2011). Course reforms that did not require additional funding or additional class commitments, such as time and/or credit, were desirable.

Significant results were published by Ralph Preszler (2009). A traditional biology course consisting of 3-hour of lectures per week was replaced by a reformed course that had 2-hours of lecture plus 1-hour of peer-led workshop per week. Workshops included cooperative learning activities such as: working through case studies, learning-skills sessions, and solving problem sets. Students worked in teams of three or four, facilitated by upper-level biology students called "biology learning catalysts" or BioCats. Results showed grades for both minority and majority students improved in the reformed course but there was greater improvement for underrepresented minority (URM) students and female students in the reformed course (Preszler 2009). "Underrepresented minority students experienced a 47% increase in the proportion of students earning 'A's or 'B's whereas non-URM students showed a 36% increase" (Preszler 2009, 187). And similarly, "The increase in the proportion of females earning 'A's or 'B's with the advent of workshops was 49%; the increase in the proportion of males earning 'A's or 'B's was 37%" (Preszler 2009, 187).

These results resonate with earlier results by sociologists Elaine Seymour and Nancy Hewitt. In 1997 they investigated why students drop out of STEM by interviewing over 300 undergraduates from seven different U.S. schools. It was found that the 'weed out philosophy' commonly found in STEM courses was disproportionally affecting women and minorities, and these students that switched majors were not "noticeably poorer students than the persisters" (Seymour and Hewitt 1997, 295). In fact, all students shared this concern. Of course, student perceptions, attitudes, and experiences in STEM are a complex multilayered story, but one common thread was that female students tended to excel when they had the opportunity to develop an individual connection with their instructors (Seymour and Hewitt 1997).

Another significant course intervention was published by David Haak et al. at the University of Washington-Seattle (Haak et al. 2011; Freeman, Haak, and Wenderoth 2011). Introductory STEM biology courses were taught with 'increased structure' that included active learning as compared to a traditional lecture style course. This concept of 'highly structured course design' was defined by activities such as: reading quizzes, extensive in-class activities, required preparation for in person class meetings, clickers in class, and weekly practice exams. "…highly structured courses assign daily and weekly active-learning exercise with the goal of providing constant practice with the analytical skills required to do well on exams." (Freeman, Haak, and Wenderoth 2011, 176). The hypothesis of this study was that active learning exercises combined with frequent formative assessment would not only produce higher learning gains, but also produce students that have acquired stronger learning skills. This is a desirable effect as research shows that the achievement gap and high failure rates especially in gateway courses is correlated to student preparedness (Fullilove and Treisman 1990; Slavin et al. 2009). On average STEM gateway courses (biology, chemistry, computer science, engineering, mathematics, and physics) have a failure rate of one-third (Freeman, Haak, and Wenderoth 2011). This study was particularly interested in upholding the rigors of introductory biology science content and at the same time reducing the failure rates. It was found that the data supported the hypothesis and the increased course structure lower failure rates from 18.2% to 6.3% (Freeman, Haak, and Wenderoth 2011). The role of reading quizzes was especially of note. The idea being that the reading quizzes allowed the students to take on the job of learning the "easy stuff" at home, which then frees up more class time for the higher learning objectives. This addresses the issue of faculty avoiding active learning because content coverage would be dramatically reduced (Freeman, Haak, and Wenderoth 2011). "It is not possible to work at the application or analysis level without knowing the basic vocabulary and concepts. We see reading quizzes as an essential component of successful, highly structured course designs." (Freeman, Haak, and Wenderoth 2011, 184). For underrepresented students, (defined by enrollment in the University of Washington's Educational Opportunities Program-EOP on campus which is typically 76.5% minority), results were even more dramatic. There was a 45% drop in the achievement gap between minority and majority students (Haak et al. 2011). Based on this work, the concept of using graded extra practice and increased active learning activities to support underprepared students in STEM pathways has been termed the 'Carnegie Hall hypothesis' (named for a hypothetical tourist who asks a New Yorker how to get to Carnegie Hall, and the local person answers, 'Practice makes perfect.') (Haak et al. 2011). To summarize this point:

> *Highly structured course designs provide practice with problem-solving and reasoning skills that may be new to high-risk students in introductory college STEM courses. Specifically, active learning that promotes peer interaction makes students articulate their logic and consider other points of view when solving problems, leading to learning gains.* (Haak et al. 2011, 1215)

A related study by Sarah Eddy and Kelly Hogan (2014) specifically looked at the effectiveness of moderately increased course interventions across diverse learner populations, including: subdivisions of underrepresented minorities and first generation students. This work is a directed attempt to gain finer resolution across ethnicities and student learning gains, and is being called 'second-generation education research' (Freeman et al. 2014; Eddy et al. 2013). The critical issue being addressed here is: now that research shows active learning works, what are the identifying elements that make it more effective? Building on the work of Freeman et al. (2011) using increased course structure to produce more effective learning, this study also looked at student behaviors and perceptions in the intervention course, (introductory biology), which was located at the University of North Carolina. The concept of 'moderately structured course design' was defined by activities such as: reading quizzes, clicker questions, worksheets, case studies, and graded review assignments. The results of this study found that: (1) failure rates dropped from 26.6% to 15.6% (a decrease of 41.3%); and (2) exam scores were higher by 3% for all students and another 3% for African-American students (Eddy and Hogan 2014). These results were similar to a previous report by Beichner et al. (2007) in which the physics SCALE-UP intervention worked best for African-American and for White students only.

In regard to student perceptions, behaviors, and experience of the class, Eddy et al. (2014) found many factors were at play but three factors were significant: time allocation, classroom culture, and course value. Students in the moderately structured intervention course invested more time in the course and their higher grades reflected that accountability. Another significant factor that was classroom culture. Classes that were more highly structured allowed for more of a sense of community to be established and this has been correlated to increased performance especially for first-generation students (Walton and Cohen 2007; Walton et al. 2012). And finally, it was found that increasing the course structure caused the students' perception of the course value to increase. "In the increased-structure course, students come to class having read the book, or at least worked through the preparatory assignment, and thus have begun the knowledge acquisition stage of learning" (Eddy and Hogan 2014, 456).

A 2019 study of introductory calculus based physics courses taught at Harvard found that students who experienced active learning actually learned more, but their perception of learning was lower than their peers in the lecture-only course (Deslauriers et al. 2019). The evidence seemed to suggest that when students experience the "increased cognitive efforts" associated with active learning they have the impression that they are learning less. One conclusion was that instructors should be cautious when using student evaluations, as they may contain this negative bias (Deslauriers et al. 2019).

Previous work from the field of cognitive psychology published by Heegung Kim (2002; 2008) found that the very idea "getting students to talk is a way to make them 'better' thinkers" (Kim 2002, 828) is rooted in a cultural assumption that that goes back to the Greeks. Homer taught that "one of the most important skills for a man to have to be that of the debater" (Kim 2002, 829). Socrates believed that people had knowledge but it had to be recovered or drawn out by verbal reasoning (i.e. the Socratic method) (Barnes 1965; Kim 2002; Hunt 1993). Kim's study involved comparing the cognitive processes between East-Asian American students and European American students at Stanford University in the context of a psychology class. Participants were randomly assigned to two groups to work on solving problems. In the treatment group the students were instructed to think out loud while solving the problems, while the control group was given no additional information. Results showed that talking was indeed a cultural practice. When European American students thought out loud while solving problems it either helped them or was neutral. When the East-Asian American students talked out loud, performance was impaired. Indeed, it is not an assumption in East-Asian cultures that talking is always positive. Silence is valued. Indirect and nonverbal communication are more common (Azuma 1986; Clancy 1986; Kim 2002; Gudykunst, Gao, and Franklyn-Stokes 1996; Smith and Bond 1999). "East Asians believe that states of silence and introspection are considered beneficial for high levels of thinking...this assumption is well expressed in Buddhist and Taoist practices, such as meditation" (Kim 2002, 829). Basic cognitive processes, psychological tendencies, and biological effects were not consistent when East-Asian American and European American students were asked to verbalize their thoughts (Kim 2008). The relationship between talking and thinking, (or silence and thinking), appears to depend on a person's cultural lens.

Another psychology study published by Krishna Savani et al. (2013) involved comparing performance of European American students at Stanford University to Mexican students at the University of Guadalajara, Mexico based on emotions and relationships. Students were asked to write about recent emotional situations. The first part of the study showed that Mexican students tended to experience 'interpersonally engaging emotions' or feelings that bring the self closer to others more frequently than their American counterparts. European American students were more likely to experience 'interpersonally disengaging emotions' or feelings of an independent individual (Savani et al. 2013, 684). This was consistent with earlier research that found a similar conclusion for Japanese students at the Tokyo Woman's Christian University (Kitayama, Markus, and Kurokawa 2000; Kitayama, Mesquita, and Karasawa 2006). Japanese students were more likely to feel socially engaging emotions such as friendliness and guilt, as compared to American students who showed more disengaging emotions of pride and anger. Interestingly, engaging emotions were also tied to more general sense of well-being as seen in the Japanese students and likewise their culture. The results from the Savani et al. study (2013) were found to be directly related to motivational effects and performance. "Mexican participants solved more word search puzzles after recalling instances in which they experienced positive interpersonally engaging emotions, and fewer after recalling negative interpersonally disengaging emotions; in contrast, there were no differences by condition for European Americans" (Savani et al. 2013, 692). The implication was that in the Mexican cultural context relationships that are positive and emotionally close, (simpatico/a and personalismo), positively affected motivation and engagement for the Mexican students; and a negative interpersonally engaging experience undermined their performance. Apparently Mexican students were more highly sensitive to interpersonal engagement, and that experiencing positive and warm relationships was the most important emotional dimension of doing well (Savani et al. 2013).

3.1.4 Applications of Active Learning Theory Relevant to this Study

3.1.4.1 Astronomy Education Research (AER)

Astronomer and educator, Andrew Fraknoi (2001), published a report entitled, "Enrollments in Astronomy 101 Courses", using data compiled by the American Institute of Physics (AIP) (Mulvey and Nicholson 2001), it was found that 250,000 students take introductory astronomy (ASTR 101) courses in the U.S. each year. For many of these students as non-majors, this is their only college-level science course they will take. Astronomy has been called the 'gateway course to science' (De Leo–Winkler, Canalizo, and Wilson 2016). About three-quarters of the ASTR 101 course enrollment comes from combined Physics and Astronomy departments where no astronomy degrees are offered (Mulvey and Nicholson 2008) so it follows that astronomy education research (AER) overlaps with physics education research (PER) to some degree. The main differences between introductory college-level astronomy and physics courses are: ASTR 101 courses typically have little math, lab sections are not always included with ASTR 101 courses, and ASTR 101 is not a sequential course.

Early contributions to this discipline-based research (DBR) of astronomy education research (AER) were made by David Targan who investigated students' understanding of the moon and later created "The Assimilation and Accommodation of Concepts in Astronomy" (1988). Timothy Slater worked with K-12 teachers regarding change in attitude after participating in a constructivist-based astronomy workshop (1993). And Rebecca Lindell also worked on assessment and curriculum in ASTR 101 (2001). At this same time contributions in AER were made by Michael Zeilik, who received NSF funding to reform introductory astronomy courses at the University of New Mexico in 1992 (Bailey and Lombardi 2015), and published the first astronomy concept inventory, called the 'Astronomy Diagnostic Test' in 2002 (Zeilik 2002). Zeilik and Vicky Morris published a study on misconceptions and attitudes in astronomy (2003) by comparing two introductory astronomy courses, one for science majors (ASTR 270) and one for non-majors (i.e. ASTR 101). It was found that both the science majors and the non-majors come into the course with similar misconceptions, and the students that are science majors exhibited the same size gain on the ADT (<g> 0.5) (Zeilik and Morris 2003). Surprisingly it was also found that both groups started the course with a positive attitude towards astronomy, and both groups' attitude remained the same after the course (Zeilik and Morris 2003).

In 1997 the Conceptual Astronomy and Physics Education Research (CAPER) team was established at the University of Arizona. Later AER researchers such as: Slater, Zeilik, Lindell, Grace Deming, Gina Brissenden, Ed Prather, and Beth Hufnagel worked to establish other diagnostic tools, curriculum, and workshops. This team was called the Collaboration for Astronomy Education Research (CAER). A major contribution by the CAER team was the second version of the Astronomy Diagnostic Test (ADT v2.0) released June 1999 (Hufnagel 2001; Deming 2002a). The ADT was established as the standard concept inventory for all college-level introductory astronomy courses, as reported in 2007 it contained a national database including over 5,000 pretest and 3,500 posttest results from 100 classrooms across the U.S. (Brogt et al. 2007).

By 2006 the updated AIP report found a nearly 15% increase in the number of students who were enrolled in ASTR 101 as compared to five year earlier. In addition there was an unprecedented 61% increase of bachelor degrees awarded in astronomy in the U.S. in 2000-2001 (Mulvey and Nicholson 2008). In 2008 Slater and the CAPER team were based at the University of Wyoming and the Center for Astronomy Education (CAE) remained based at the University of Arizona (Bailey and Lombardi 2015). This same year, Slater describes as "the first big wave of astronomy education research (AER) dissertations" (2008, 1).

David Hudgins et al. (2006) presented results from a study showing the effectiveness of 'ranking tasks' in introductory college-level astronomy courses. The results showed a 16-percentage point increase in content learning for students participating in the collaborative ranking tasks across eight key concepts in astronomy. In addition, an attitude survey measure 83% of the students in the 16-week study felt that the ranking tasks help improve their understanding of astronomy. An area of investigation in AER is active engagement strategies in astronomy education. Various published active engagement strategies in ASTR101 were outlined by Bailey in 2011. These interventions included: peer instruction, science literacy activities, night labs, and collaborative class activities (Bailey 2011). Measurement tools included: ADT v2.0 (Hufnagel 2002), Star Properties Concept Inventory (Bailey 2006), Lunar Phases Concept Inventory (Lindell and Olsen 2002), Light and Spectroscopy Concept Inventory (Bardar et al. 2006), self-created attitude surveys, interviews, student evaluations, research observations, and self-created questions (Bailey 2011).

In the 2014 American Institute of Physics (AIP) report, enrollments in college-level introductory astronomy courses were steadily increasing, with a 10% increase over the past decade (Mulvey and Nicholson 2014). The latest published report from the AIP in 2017 shows the number of bachelor's degrees in astronomy in the U.S. has been increasing over the past 15 years (Mulvey and Nicholson 2017). As the number of PhD's in astronomy has remained constant since 1987, the number of bachelor's degrees in astronomy has nearly doubled. "The 535 astronomy degrees conferred in the class of 2017 represents a 14% increase over the previous year and signifies another all-time high" (Mulvey and Nicholson 2017, 1). Also in the last thirty years, the number of departments offering astronomy bachelors' degrees has nearly doubled (Mulvey and Nicholson 2017).

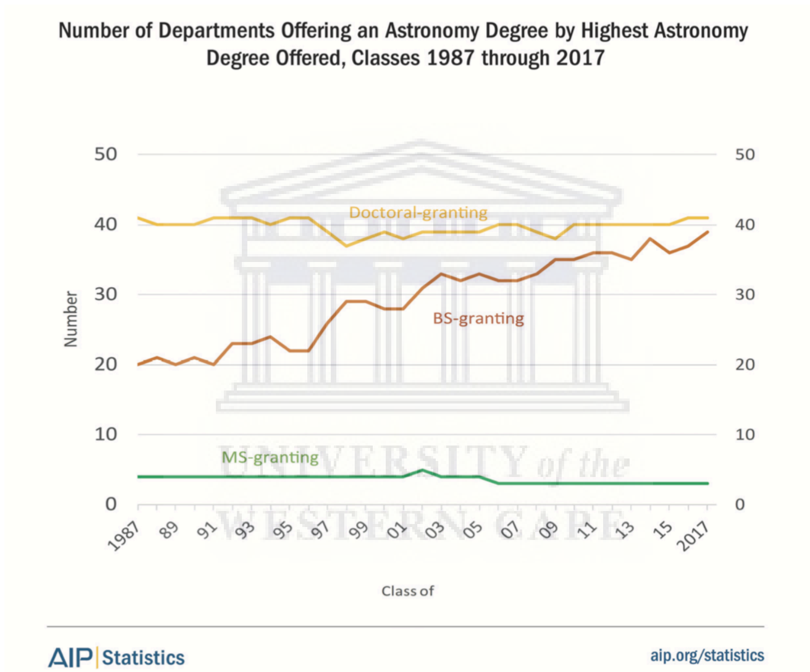


Figure 10 - AIP data showing the historic increase in astronomy bachelor's degrees in the U.S.(Mulvey and Nicholson 2017, 6)

From these statistics we can conclude that there is a growing momentum and interest in astronomy particularly at the undergraduate level. This study involves ASTR 101 courses, which are introductory and not intended for majors. This growing interest in astronomy is relevant as introductory astronomy have been called 'the gateway course in STEM'. As Fraknoi pointed out nearly a decade ago, there were one-quarter of a million students taking introductory astronomy college courses in the U.S. This is a huge number of students. Identifying and measuring the role of culture as a key variable in STEM student learning could potentially have an enormous impact, especially for increasing equity and participation by URM students in STEM.

3.1.4.2 Classroom Observation COPUS

In the past three decades, a transformation in STEM higher education pedagogical approaches has been occurring (Stains et al. 2018; Wieman and Gilbert 2014; Lund and Stains 2015; PCAST 2012; Targan 1988; Treisman 1992; Smith et al. 2013; Knight and Wood 2005). In spite of the vast amount of literature that has been published on the benefits of active learning, there are few large-scale reports on how many instructors are actually using active learning in the classrooms and which practices are being implemented. There was a need to design better ways to evaluate teaching and establish baseline data. Empirically-based studies, observational instruments, and assessment tools are the essential apparatuses to monitor teaching practices and possible reform practices in the college classroom at the national level in STEM.

Carl Wieman and Sarah Gilbert published the "Teaching Practices Inventory (TPI)" (2014) as a way for post-secondary instructors of mathematics and science to take an inventory of their teaching practices and offers a means of improvement through self-reflection. Wieman argues that current evaluations were unreliable, such as student course evaluations, peer-observations, teaching portfolios, and not based on effective research-based teaching practices. The TPI assessment tool used is a questionnaire consisting of eight categories of teaching practices: course information provided; supporting materials provided; in-class activities; assignments; feedback; other (diagnostics); training and guiding of TAs; and collaboration or sharing in teaching (Wieman 2015). Evidence-based STEM education research in active learning was used to construct the 10-minute survey. Data was collected on the teaching practices of more than 200 STEM courses at the University of British Columbia (Wieman and Gilbert 2014). It was found that there was a large range of teaching practices within a department at the same institution; high scoring courses use many different teaching practices and low scoring courses use only a few (Wieman and Gilbert 2014).

In contrast to faculty peer-observation, which is open-ended, observer dependent, and not standardized, several structured observational protocols were developed. Early examples of such protocols include the Inside the Classroom: Observation and Analytic Protocol (Weiss et al. , 2003) (Pasley et al. 2004) and the Reformed Teaching Observation Protocol (RTOP) (Piburn and Sawada 2000) developed by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers. RTOP uses 25 items that connect a teaching practice with its level of use in the classroom on a Likert scale. A disadvantage of RTOP is the time required for training. Later, the Teaching Dimensions Observation Protocol (TDOP) was developed (Hora, Oleson, and Ferrare 2013) but nearly 50 codes and a demanding training of observers was found to be a barrier for wide-spread use. After a two-year iterative process in 2013 Michelle Smith, Francis Jones, Sarah Gilbert, and Wieman developed Classroom Observation Protocol for Undergraduate STEM (COPUS) (Smith et al. 2013). This protocol uses 25 codes recording behavior of students and instructor at 2-minute intervals and requires only a few hours of training. Sample codes for the instructor include: lecturing, asking questions, moving through the class guiding, etc. Sample codes for the student include: listening, working in groups, answering questions, waiting, etc. Coding also includes level of engagement from low (below 20%); medium, or high (80% or greater). Smith et al. published results of a campus-wide study using COPUS. The study consisted of 52 STEM courses across 13 STEM departments at the University of Maine (2014). Results showed that: (1) instructor teaching methods are not binary (traditional lecture only or active learning only) but rather exist on a continuum; (2) that student behaviors vary greatly in courses with varied amounts of lecture; (3) faculty are generally aware of their teaching practices; and (4) faculty are not always influenced by class size in their choice of teaching practices (Smith et al. 2014). The authors recommend that results such as these should be used to characterize the general state of teaching, to provide feedback to instructors, and identify professional development needs.

> *…most faculty members fall somewhere in the continuum between pure lecturing and primarily active-engagement instruction. Emphasis should be on programs that increase awareness of teaching practices currently in use across campus and on strategies that can help faculty members gradually shift where they are in the continuum in order to better meet the needs of their students.* (Smith et al. 2014, 634)

Travis Lund et al. (2015) published a research study on active learning teaching practices in STEM using both the COPUS (Smith et al. 2013) and RTOP (Piburn and Sawada 2000) protocols. The participants of this study were 73 faculty members in 28 different research-based universities in the U.S. Disciplines included: physics, chemistry, mathematics, and biology departments. It was found that (1) faculty employ many different teaching practices within a short time period such as one week; (2) more experienced teachers were more likely to use student-centered teaching practices; (3) student centered teaching practices were more likely to be used in lower-level undergraduate courses; and (4) classroom environments such as large-enrollment courses and fixed layouts are not necessarily barriers to implementation of student-centered instructional practices (Lund et al. 2015).

In a related study based on 120 survey results and 66 classroom observations, Lund and Marilyne Stains (2015) focused on what factors influence an instructors use of active learning teaching practices in STEM. Participants included faculty members from a single Midwest university in departments of chemistry, physics, and biology. It was found that lecturing was in use 56% of the class-times (53% in biology, 69% in chemistry, and 45% in physics) (Lund and Stains 2015). Comparatively collaborative learning was happening on average 4% of the class-times (11%, 0%, and 0% respectively) (Lund and Stains 2015). To gain further insight on the factors that motivate teaching practice results were divided into three areas: awareness, interest, and adoption of evidence-based instructional practices (EBIP). Here it was found that in all three subject areas respondents professed awareness of 65% of the evidence-based instructional practices (EBIP), such as clickers, animations, peer instruction, case studies, etc. Next, it was found that faculty professed interest in approximately 6 of the 17 EBIPs (35% or a 45% decrease as compared to awareness). Adoption of EBIPs was found to be 3.5 out of 17 EBIPs overall, highest in physics, lowest in chemistry. Although the percentage of faculty using at least one EBIP was on average 76% across all three disciplines, physics was found to have more student-centered classroom attitudes than chemistry and biology (Lund and Stains 2015). They suggest three factors that influence instructional design: communication channels (colleagues, journals, conferences); contextual influence (department factors and learning environment); individual influences (attitudes and beliefs about teaching). Not surprisingly, there are complicated relationships within departments and institutions in addition to individual experiences and preferences.

Two significant studies using the COPUS observation protocol were both published in 2015 (Achen and Lumpkin 2015; Connell, Donovan, and Chambers 2016). The first study was done at a large public university in the Midwest U.S. using an "Introduction to Sport Management" course over one semester. Small adaptations were used to tailor the codes to the specific teaching practices of the instructor such as including codes for 'jeopardy' and 'videos'. In addition, student survey data was collected throughout the semester to gain student perceptions of the various interventions. Results based on COPUS were: (1) students spent on average 57% of class-time engaged in non-lecture activities, mostly group work at 16%; and (2) on average 30% of class-time involved lecture. Results based on the survey were: "Students responded the average amount of time the teacher should lecture during a class was 61.2%. The post-course survey revealed students believed teachers should lecture 66.3% of the time" (Achen and Lumpkin 2015, 4). Student views of the ideal amount of lecture time in a class remained the same. Interestingly students also responded overwhelmingly that the active-learning activities were enjoyable and had "a significantly higher impact on their learning" (Achen and Lumpkin 2015, 5).

The second study used COPUS to measure engagement in a large enrollment introductory non-major undergraduate course (Bio 101) at Western Washington University in 2015 (Connell, Donovan, and Chambers 2016). The same instructor taught two versions of the same introductory biology course during the same quarter. The study had two groups, the 'Extensive section' implemented many active-learning pedagogies and the 'Moderate section' which used fewer student-centered course interventions. The research questions were the following: do the students in the Extensive section gain increased content knowledge; and do students exhibit increased sophistication in their views about biology due to participation in the extensive section? Results showed that: (1) students in the Extensive section had significantly higher learning gains as measured by course exams 72% versus 63.6%, and (2) although both sections had preassessment scores of 44%, the post-assessment scores were higher for the Extensive section at 58.5% versus 54.6% for the Moderate section (Connell, Donovan, and Chambers 2016). To assess student attitudes the Views About Sciences Survey Form B12 was used (I. Halloun and Hesteness 1996). Students' attitude profiles at the beginning of the course in both sections were similar, and by the end of the course 20% of the students in the Extensive section were classified as 'experts' as compared to the Moderate section at 15% (Connell, Donovan, and Chambers 2016). In the Extensive section 53% of students preferred active learning exercises as opposed to lecture, while 33% still preferred lecture-based classes. The researchers noted that "We found that using several active-learning strategies coupled with consistent formative assessment led to better student outcomes compared with using fewer active-learning strategies in a more teacher-centered classroom" (Connell, Donovan, and Chambers 2016, 13).

In one important large scale study published (Stains et al. 2018) classroom observation data was collected from over 2,000 classes across multiple national intuitions with participation of over 500 STEM faculty members. Disciplines included: chemistry, biology, physics, astronomy, zoology, and ecology. The observation instrument, Classroom Observation Protocol for Undergraduate STEM disciplines (COPUS) (Smith et al. 2013) was adapted for this study due to its broad use and because it has been "empirically demonstrated to provide valid characterizations of instructional practices in STEM classrooms" (Stains et al. 2018, 3-4). Results showed: (1) a wide range of instructor teaching practices were occurring so at least four observations were needed per instructor; (2) the most common instructor behavior was lecturing at 75% of class-time; and (3) students primarily listen to the instructor at 87% of the class-time. To gain insight on non-lecture/listening behavior, a cluster analysis called "latent profile analysis" was used. Instructor codes: lecture, posing questions, clicker questions, and one-on-one work with students were combined. Student codes: group work on clicker questions, group work on worksheets, other group work, and asking questions were combined. Three significant class profiles were found: 'Didactic' (80% or more lecture), 'Interactive Lecture' (between 79%-51% lecture), and 'Student Centered' (50% or less lecture). It was found that 55% of the observed classes were Didactic; 27% Interactive; and 18% or nearly one-fifth of the instructional styles were Student Centered (Stains et al. 2018). These results were then generalized:

> *Given the sample size and diversity of courses and disciplines represented, we are confident that the profiles and broad instructional styles provide a reliable picture of the current instructional landscape in undergraduate STEM courses taught at doctorate-granting institutions.* (Stains et al. 2018, 5)

The report concludes that institutions of STEM disciplines should "reflect on practices and policies that sustain this status quo and identify systemic reform strategies" (Stains et al. 2018, 6). Furthermore, the report challenges studies in which faculty report class size and classroom layout as barriers to student-centered pedagogies. In fact, half of the classrooms that had the smaller class size and the flexible physical layout did not use active learning. The recommendation is for increased pedagogical training (Stains et al. 2018).

3.1.4.3 Analysis of the Scholarship on Active Learning

This section will present the author's analysis and conclusions about the state of active learning in STEM in the U.S. First, it is deeply disturbing that the average failure rate in STEM courses is 33% as was confirmed in the Freeman (2014) meta-analysis. To say that the failure rate improved from one student out of three (33.8%) to one student failing out of every four-and-a-half students (21.8%) continues to show that STEM higher education is in need of urgent change. This statistic represents a tremendous loss of talented young people, especially students of color. Secondly, the most interesting result is the Eddy and Hogan (2014) analysis of why the 'moderately structured course' resulted in gains. According to the researchers, students spent more time on the course because there was a greater sense of community and students valued the class because they were held accountable. This points to an underlying common ground with Indigenous knowledge systems (IKS), as Cajete (2000), Wilson (2008), and others have pointed out, *relationships* are the key. Learning is not solely about the individual any more than science is void of culture. Third, there is an undeniable gain when a blend of active learning and lecturing takes place. And yet in the Stains meta-analysis (2018) of over 2,000 STEM courses, faculty were still lecturing 75% of the time, and students were listening 87% of the time. This is a shocking result. We know that the dominant course delivery used in universities today, the lecture, dates back at least to the European Middle Ages (476 AD-1453 AD). Evidence (Stuart and Rutherford, 1978) shows students can really only listen to a lecture for 30 minutes. So why is the lecture mode so dominant forty-two years later? Where is our creativity in communicating our most cherished ideas in science?

3.2 Culturally Relevant Pedagogy and Culturally Responsive Pedagogy (CRP) Theories

In 2011 the United States reached a new milestone. For the first time in American history, births of white babies were outnumbered by minority births (49.6% non-Hispanic whites as compared to 50.4% for Hispanics, Blacks, Asians, and Mixed-race) (Tavernise 2012). What implications does this demographic transformation have for K-12 education? The minority student population in the U.S. grades K-12 is increasing rapidly. In 2014, according to U.S. Department of Education projections, the demographics of the nation's classrooms were set to break a historic barrier because, "For the first time, the majority of students in America's public schools would no longer be white" (Fay 2018). As identified in the quote below, Hispanic and Asian/Pacific Islander K-12 student populations increased:

> *Between fall 2000 and fall 2015, the percentage of students enrolled in public elementary and secondary schools who were White decreased from 61 to 49 percent. The percentage of Black students also decreased during this period from 17 to 15 percent. In contrast, there was an increase in the percentage of students enrolled in public schools who were Hispanic (from 16 to 26 percent) and Asian/Pacific Islander (4 to 5 percent) during this time period.* (National Center for Education Statistics 2019a)

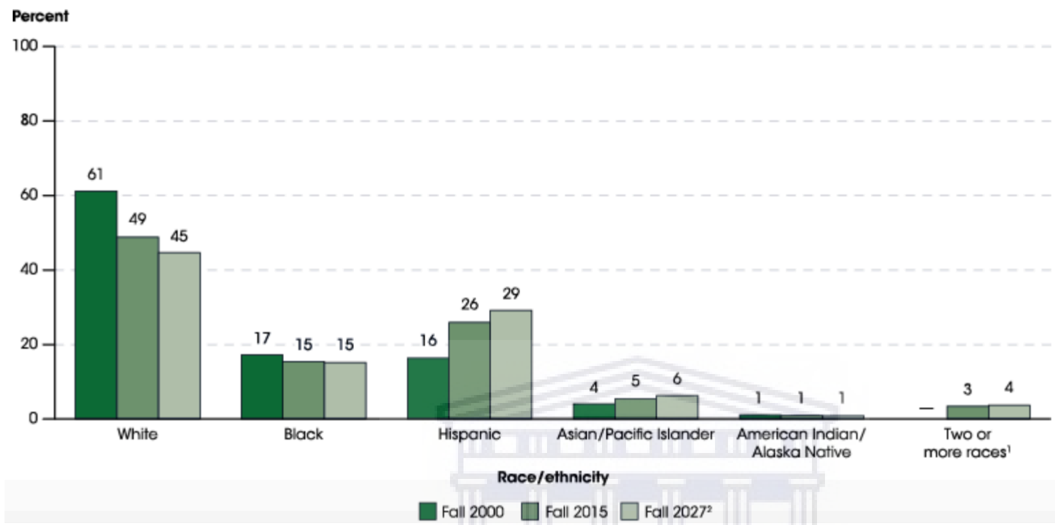


Figure 11- Percentage distribution of public school students enrolled in prekindergarten through 12th grade, by race/ethnicity: fall 2000, fall 2015, and fall 2027, (National Center for Education Statistics 2019a)

While the ethnic makeup of elementary and secondary school students is shifting rapidly, the ethnic background of K-12 educators remains predominantly white. In the U.S the racial/ethnic distribution of elementary and secondary school teachers is 80% white in spite of research showing that having a diverse teaching staff can have a positive impact on all students' attitudes, motivation, and achievement (Egalite and Kisida 2018; Egalite, Kisida, and Winters 2015).

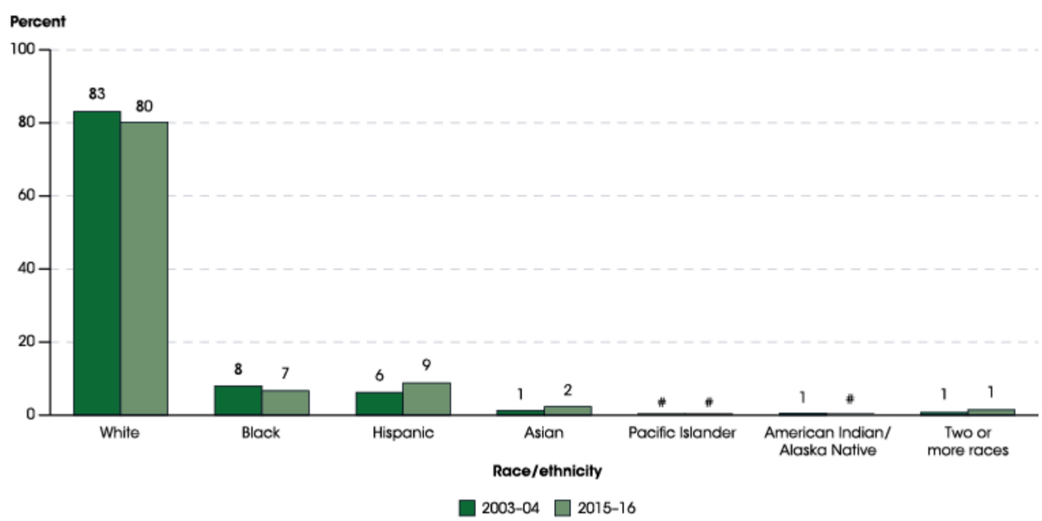


Figure 12 - Percentage distribution of teachers in public elementary and secondary schools, by race/ethnicity: School years 2003–04 and 2015–16, (National Center for Education Statistics 2019d)

In addition, there is research showing that minority teachers may have more positive expectations for minority students’ achievement that nonminority teachers (Gershenson, Holt, and Papageorge 2016). At the same time the U.S. has a troubled record in educating minority youth. The racial gap in achievement persists in both math and reading (Plucker, Burroughs, and Song 2010). According to the National Center for Education Statistics, “From 1990 through 2017, the average mathematics scores for White 4th- and 8th-graders were higher than those of their Black and Hispanic peers” (2019c). And similarly, “From 1992 through 2017, the average reading scores for White 4th- and 8th-graders were higher than those of their Black and Hispanic peers…” (National Center for Education Statistics 2019b).

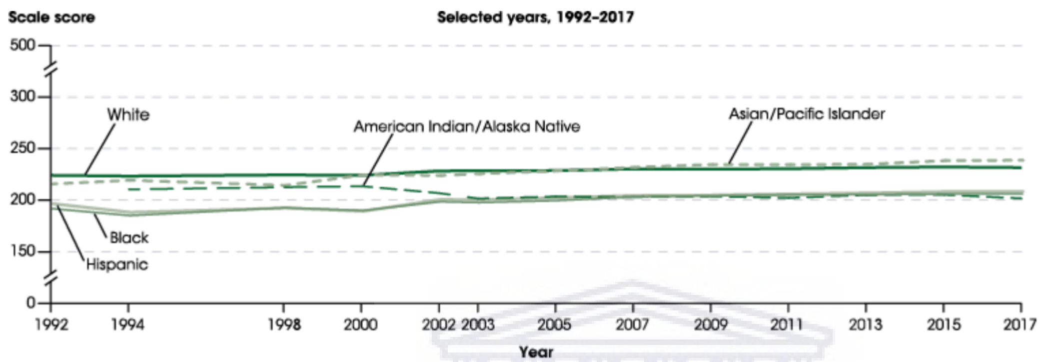


Figure 13 - Average National Assessment of Educational Progress (NAEP) reading scale scores of 4th-grade students, by race/ethnicity: Selected years, 1992–2017, (National Center for Education Statistics 2019b)

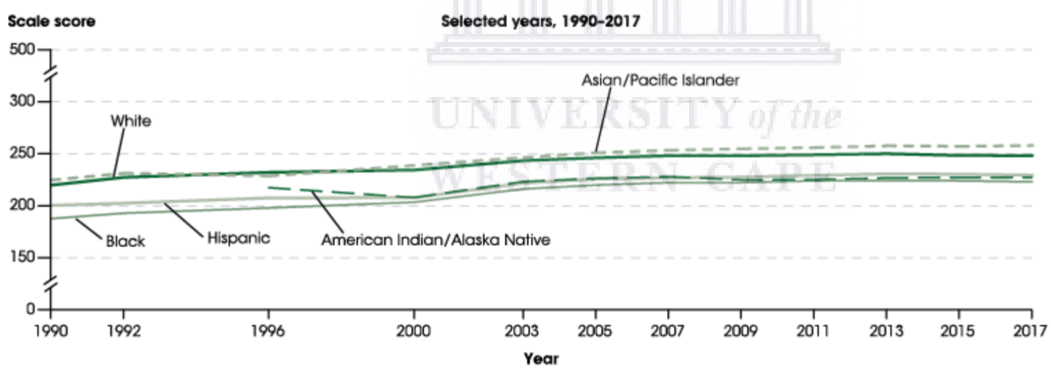


Figure 14 - Average National Assessment of Educational Progress (NAEP) mathematics scale scores of 4th-grade students, by race/ethnicity: Selected years, 1990–2017, (National Center for Education Statistics 2019c)

The implications of this educational disparity are many: education attainment, postsecondary education, career choices, employment, earnings potential, civic participation, and so on. This critical situation, of the mismatch between the ethnic makeup up public school students as compared to their teachers has been referred to as a “cultural discontinuity” (Brown-Jeffy and Cooper 2011, 66). Strategies were needed to address and assist teachers in the ever-increasing ethnic diversity of their students.

3.2.1 Culturally Responsive Pedagogy (CRP) A Brief Overview

Twenty-five years ago Gloria Ladson-Billings wrote, “For almost 15 years, anthropologists have looked at ways to develop a closer fit between students’ home culture and the school.” (1995a, 159). At that time in the 1980s there was a growing focus on examining the mismatch between teaching styles and home-community of students. Sociolinguistic research with Indigenous communities, such as work done by Kathryn Au and Cathie Jordan on Hawaiian culture (1981) and Gerald Mohatt and Frederick Erickson on Odawa culture (1981) helped to gain insight on developing viable strategies and learning environments for underserved students. Au and Jordan describe an approach to teaching reading to Hawaiian students that was consistent with the children's culture (1980). They go on to describe the methodology in more detail, "The analysis is felt to be of particular interest because this reading lesson (involving 'talk story') is an example of a culturally appropriate context for learning, one which is comfortable for the children, comfortable for the teacher, and also productive of academic achievement. It represents a hybrid setting…" (Au 1980, 112).

Jacqueline Irvine developed the concept of 'cultural synchronization' to speak to the student-teacher cultural disconnect (1990). There was a call to shift away from abstract educational methodologies towards an understanding of "humanizing pedagogy" which meant "[a pedagogy] that respects and uses the reality, history, and perspective of students as an integral part of educational practice" (Bartolome 1994, 173).

In the Ladson-Billings in 1990s at the University of Wisconsin contributed significantly to education research by carefully studying the characteristics of successful teachers of African American students. What were they doing differently that made their teaching so extraordinary? Using these insights gained from the exemplary teachers of African-American students, Ladson-Billings defined "culturally relevant pedagogy".

> *Culturally relevant pedagogy rests on three criteria or propositions: (a) Students must experience academic success; (b) students must develop and/or maintain cultural competence; and (c) students must develop a critical consciousness through which they challenge the status quo of the current social order.* (Ladson-Billings 1995a, 160).

Ladson-Billings goes on to describe a theoretical framework for culturally relevant pedagogy based on three concepts: (a) the conceptions of self and others held by culturally relevant teachers, (b) the manner in which social relations are structured by culturally relevant teachers, and (c) the conceptions of knowledge held by culturally relevant teachers (Ladson-Billings 1995b, 478).

Thus, culturally relevant pedagogy is a way for the teachers to begin to acknowledge and value the culture of their students, seeing it as a dynamic resource, a strength instead of a weakness. In this way "culturally relevant teachers are a crucial bridge between current realities and more empowering educational experiences for students of color" (Lipman 1995, 207). Teachers who practice culturally relevant teaching understand that student diversity requires a diversity of approaches (Bainbridge and Lasley 2002). Ladson-Billings argued that to close the achievement gap, one critical element is that the teacher must believe that all students can succeed (Ladson-Billings 1994; 1995a). Her analysis of the exemplary teachers' concept of self and others was as follows:

Table 2 - Concept of Self and Other (Ladson-Billings 1994, 38; Bainbridge and Lasley 2002; Ladson-Billings 1995a)

Culturally relevant:	Assimilationist:
Teacher sees herself or himself as an artist, teaching is an art.	Teachers sees herself or himself as technician, teaching as a technical task.
Teacher sees herself or himself as part of the community and teaching as giving something back to the community, encourages students to do the same	Teachers sees herself or himself as an individual who may or may not be a part of the community; she or he encourages achievement as a means to escape community
Teacher believes all students can succeed	Teacher believes failure is inevitable for some
Teacher helps students make connection between their community, national, and global identities.	Teacher homogenizes student into one "American" identity
Teacher sees teaching as pulling knowledge out, like mining	Teacher sees teaching as "putting knowledge into", like banking.

Ladson-Billings provides seven guidelines for how classroom teachers can build culturally relevant pedagogy into the classroom (2006, 30-37). She refers to the seven elements of culturally relevant teaching:

1. Social Contexts-The culturally relevant teacher will assume an asymmetrical relationship exists between students of color and society, and prepare students to 'combat inequity by being highly competent and critically conscious'.
2. Students-The culturally relevant teacher should practice 'informed empathy', which means they feel with the student rather than feel for them.
3. Curriculum-An effective culturally relevant teacher must be able to analyze, critique, and reconstruct the curriculum. They must realize that curriculum is embedded with cultural assumptions and not an idealized, neutral document.
4. Instruction-Practitioners of culturally relevant teaching must use a wide variety of teaching styles, strategies, and techniques to give the widest range of students access to learning. "…their teaching must engage, cajole, convict, and perhaps even fool students into participation" (2006, 33).
5. Academic Achievement-Culturally relevant teaching involves thinking deeply about what they are teaching and ask why should students learn this. They must use many real-life and familiar examples that help the classroom come alive.
6. Cultural Competence-This means helping dominant group members become more skillful in reading the cultural messages of their students, "…helping students to recognize and honor their own cultural beliefs and practices while acquiring access to the wider culture, where they are likely to have a chance of improving their socioeconomic status and making informed decisions about the lives they wish to lead" (2006, 36).
7. Sociopolitical Consciousness-The culturally relevant teacher must help the students use the various skills they learn to better understand and critique their social position and context.

The culturally relevant teacher should know about local issues related to the school community that might be a part of the students' lives (Ladson-Billings 2006). As seen in Table 2 'Concept of

Self and Others' (Ladson-Billings 1994), culturally relevant teaching promotes a clear alternative to the mainstream or 'assimilationist' approach. What makes this alternative approach 'cultural' is that the teacher acknowledges a dynamic system of worldviews exists, (some conscious, some unconscious), that are the philosophical underpinnings of both individuals and the larger group. Upon recognizing the bigger picture, and that teaching and learning exist within this larger umbrella, the teacher believes that all students can and will succeed. It is important to note that culturally relevant pedagogy and culturally relevant teaching as originally conceived by Ladson-Billings in the 1990s had a definite component of critical consciousness that potentially led to social change, social justice, and equity for students and communities of color.

Cultural relevant pedagogy grew out of the framework of multicultural education which emerged from the civil right movement of the 1960s and 1970s in the U.S. (Banks 1993). A leading voice for the education reform movement, James Banks wrote about the goals and scope of multicultural education in 1993, "Multicultural education theorists are increasingly interested in how the interaction of race, class, and gender influences education" (Banks 1993, 4). Prior to this time in education reform there was an emphasis on curriculum reform, and the other components of multicultural education that focused on education inclusion and equity that related to these larger views were somewhat ignored (Banks 1993). Banks goes on to describe five dimensions of multicultural education: (1) Content integration, (2) Knowledge construction, (3) Prejudice reduction, (4) Equity Pedagogy, and (5) Empowering school culture.

Critical Race Theory was developed out of legal studies and scholarship in the U.S. in the mid-1970s with scholars like Derrick Bell, Alan Freeman, and Richard Delgado who were frustrated with the lack of equity gains after the civil rights movement. Here Delgado explains:

> *The critical race theory movement is a collection of activists and scholars interested in studying and transforming the relationship among race, racism, and power. The movement considers many of the same issues that conventional civil rights and ethnic studies discourses take up, but places them in a broader perspective that includes economics, history, context, group- and self-interest, and even feelings and the unconscious.* (Delgado and Stefancic 2001, 2-3)

In 1995 Ladson-Billings and William Tate advanced the concept of critical race theory in education. The connection between culturally relevant pedagogy and critical race theory is summarized as follows:

> *Culturally relevant pedagogy does not question or critically examine the structures that feed into the cultural incongruence perspective. This is where critical race theory updates the culturally relevant pedagogy framework. The broadness of race (and consequently racism) can be seen in the way it focuses specifically on how privilege has been given and truncated in American society, something culture does not do….When critical race theory is related to culturally relevant pedagogy, the centrality of race to American culture is acknowledged.* (Brown-Jeffy and Cooper 2011, 71)

Subfields have since developed which includes American Indian critical race studies (TribCrit), Latino critical race studies (LatinCrit), Asian American critical race studies (AsianCrit), critical race feminism (CRF), Disability critical race studies (DisCrit), etc.

Nearly twenty years later Ladson-Billings writes, "The way these teachers thought and spoke about their practice allowed me to discover the underlying structure of their work and describe it in ways that became useful for other teachers in a variety of settings. I identified three major domains of their work: academic success, cultural competence, and sociopolitical consciousness" (Ladson-Billings 2014). Adding critically, "Many practitioners (of culturally relevant pedagogy), and those who claim to translate research into practice, seem stuck in very limited and superficial notions of culture" (Ladson-Billings 2014, 77). This refers to educators who celebrate cultural relevancy with notions of food, dress, and various cultural holidays without a deeper understanding of cultural dimensions. Ladson-Billings urges practitioners to "take up the sociopolitical dimensions of the work, instead (of) dulling its critical edge or omitting it altogether" (Ladson-Billings 2014, 77).

In 2000 Geneva Gay, in the landmark book, "Culturally Responsive Teaching: Theory, Research, and Practice", expanded the traditional view of culture that was defined by race and ethnicity to also include an individual's beliefs, society's norms, and social groups (Gay 2000, 2010).

> *Culturally responsive teaching is defined as using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively. It is based on the assumption that when academic knowledge and skills are situated within the lived experiences and frames of reference of students, they are more personally meaningful, have higher interest appeal, and are learned more easily and thoroughly.* (Gay 2000, 106)

Teachers assume that they teach skills and neutral knowledge. Gay argues that the trouble is that: the teachers have little knowledge about how traditional teaching practices reflect European American culture, they believe that by acknowledging students' culture they are discriminating, and that education is a 'doorway of assimilation' that will ultimately help minorities 'forget about being different and learn to adapt to U.S. society' (Gay 2010, 36-46). She describes a culturally responsive teaching (CRT) *'character profile'* as follows:

1. Validating. It teaches to and through the strengths of these students. Culture as a dynamic resource; a strength and not a weakness (Lipman 1995).
2. Comprehensive and Inclusive. Develop a sense of community. Students held accountable to the group.
3. Multidimensional. This includes curriculum, learning context, classroom climate, relationships, classroom management, and performance assessments. Emotions, beliefs, values, ethos, opinions, and feelings are scrutinized along with factual information.
4. Empowering. Academic competence, personal confidence.
5. Transformative. Transcend cultural hegemony nested in much of the curriculum.
6. Emancipatory. Providing authentic knowledge allows students to feel validated, even a sense of pride.
7. Humanistic. Concerned about the well-being and dignity of all groups.
8. Normative and Ethical. Acknowledge that education is laden with culture. Acknowledge that education has failed to reflect everybody's culture. Work towards greater equity.

Gay urges teachers to consider how deeply culture impacts learning, "What is commonly thought of as cultureless mainstream U.S. schooling is, in reality, Eurocentric culturally responsive education" (Gay 2010, 45). She states:

> *Culturally responsive pedagogy simultaneously develops, along with academic achievement, social consciousness and critique, cultural affirmation, competence, and exchange; community-building and personal connections; individual self-worth and abilities; and an ethic of caring.* (Gay 2010, 52)

Gay identified five essential areas to improve learning experiences for students from culturally and linguistically diverse (CLD) backgrounds: develop a cultural diversity knowledge base; design culturally relevant curricula; demonstrate cultural caring/build a learning community; establish cross-cultural communications; and establish congruity in classroom instruction (Gay 2002; Brown 2007; Harriott and Martin 2004). Gay further emphasizes the critical importance of caring and strong academics, "Genuinely caring teachers are 'warm demanding' academic task masters. All students are held accountable for high academic efforts and performance….The success of these teachers demonstrates that the idea of caring as essential to instructional effectiveness is not merely a truism; it is a fact" (Gay 2010, 86).

In 1995 Margery Ginsberg and Raymond Wlodkowski developed the Motivational Framework for Culturally Responsive Teaching. This teaching model was built on the concept that culture and motivation are inseparable. Ginsberg states, "Since culture is inextricably connected to personal motivation, a 'seek first to understand' orientation toward students is wise" (Ginsberg 2015, 4). Their model for culturally responsive teaching (CRT) has four conditions: establishing inclusion, developing attitude, enhancing meaning, and engendering competence (Wlodkowski and Ginsberg 1995). Their work speaks to the importance of 'intrinsic motivation' versus 'extrinsic motivation' (Deci, Koestner, and Ryan 2001). Relying on research that shows 'intrinsic motivation' is linked to what a person values culturally and emotionally (Ginsberg 2015; Csikszentmihalyi 1997) and will compel learners to succeed. In comparison, 'extrinsic motivation', which the traditional school system is based on, like grades and GPA, was shown to be ineffective for approximately a third of public school students (Ginsberg 2015; Wlodkowski 2008). Note that the Indigenous knowledge system (IKS) notion of mind, body, heart, and spirit as explained by Simonelli (1994) and others is evident here. It follows that because a person is whole, they can learn best when the heart and spirit, or culture and emotion, are included in the learning process. The Motivational Framework for Culturally Responsive Teaching is a professional development program that uses strategies of peer coaching, action research, and balancing pressure with support (Wlodkowski 2003).

3.2.2 Relevant Applications of Culturally Responsive Pedagogy (CRP)

This section examines various second-generation applications and perspectives on culturally responsive teaching and learning. Specific questions here are: to what extent does CRP overlap with education goals in Indigenous classrooms? How is the framework of CRP connected to neuroscience research results? To what degree have state public schools adopted CRP into the standards? And finally, to what extent has CRP trickled into the college classroom?

> *Adopting CRT [culturally responsive teaching] goes beyond celebrating students' cultural traditions once a year. Educators who practice CRT set rigorous*

> *learning objectives for all their students and they continually build helpful bridges between what students need to learn and their heritage, lived realities, and the issues they care about. In short, culturally responsive teaching is about weaving together rigor and relevance.* (Munoz 2019, 6)

3.2.2.1 Education of Indigenous Youth and Culturally Responsive Pedagogy (CRP)

An insightful definition of culture was given by Angelina Castagno and Bryan Brayboy in 2005, "…culture is many things to many people…[it] is fluid and dynamic, and at times, fixed and stable. Like an anchor in the ocean, it is rooted to some place …The anchor shifts and sways, like culture, with the changing tides, ebbs, and flows of the ocean…" (Brayboy 2005; Castagno and Brayboy 2008, 943). The push for culturally based educational reform for Native youth goes back to 1928 and the Meriam Report. This report was a survey of conditions on reservations in twenty-six states funded by the Rockefeller Foundation. Among other recommendations, the 847-page report called for more Native teachers, more early childhood programs, and incorporation of language and culture in schools (Castagno and Brayboy 2008). The federal government was doing a poor job of supporting Native people. In the 1960s and 1970s there were several federal reports such as, "Indian Education: A National Tragedy-A National Challenge", which eventually led to increased support and more tribal control over schools. In the 1980s educational anthropology, and later multicultural education brought more focus to culturally responsive and culturally relevant pedagogies. Note that there are many interrelated terms used in the literature for example: *culturally relevant pedagogy* (Ladson-Billings 1994), *culturally responsive teaching* (Gay 2000), *culturally responsive schooling* (Castagno and Brayboy 2008), *culture-based education* (Bartell 2003). Later culture-related educational terms emerged in the research and literature, for example: *cultural competence*, with emphasis on awarenesses and sensitivities (Diller and Moule 2005) and *culturally responsive curriculum* which emphasizes students' cultures and languages and invites them to become co-constructors of knowledge (Belgarde, Mitchell, and Arquero 2002). This study most closely aligns with *culturally responsive pedagogy* (CRP) as defined by Gay (2000), which is slightly broader and less of a sociopolitical call-to-action as the original term, *culturally relevant pedagogy* as defined by Ladson-Billings in 1994.

Table 3 - How Indigenous Learning Styles are Different from Mainstream Learning Styles in the U.S. (Castagno and Brayboy 2008, 954)

Learning styles for Indigenous Youth:
visual
hands-on
connecting to real-life
direct experience
participating in real-world activities
global
seeing the overall picture before the details
creative
holistic
reflective
collaborative

circular
imaginal
concrete
simultaneous processing
observation precedes performance
naturalistic

The anticipated outcome of culturally responsive teaching (CRT) was to combat the achievement gap between Indigenous youth and mainstream, majority youth, but also to address the larger inequities associated with a lifelong struggle through the academic system. Unfortunately, there has been reluctance to implement CRT due to the emphasis in the public-school system on standardized tests and other measurable high-stakes assessment such as the U.S. policy, "No Child Left Behind Act of 2001 (NCLB)". Culture-based teaching and related efforts were increasingly left out (Castagno and Brayboy 2008). In addition, researchers Beverly Klug and Patricia Whitfield (2003) noted that many teachers believe culturally responsive teaching and methods to be inferior, even remedial as compared to the status-quo.

3.2.2.2 Culturally Responsive Pedagogy (CRP) and the Brain

Brain-based research quickly developed in the late 1990s. Researchers of brain-based learning measured direct links to brain biology and implications for teaching and learning soon emerged. Classroom relevant concerns such as: attention, memory, sensory perception, and how emotions effect learning, could be revisited in light of the new insights on the way the brain functions (Byrnes 2001; Doyle and Zakrajsek 2013; Hammond 2015; Eyler 2018; Caine and Caine 1991; Goleman 1996). Explained simply using the lens of biology, "Learning, as a brain function, is a biological process invented for survival. It is the organism responding to its environment" (Madrazo and Motz 2005, 56). Physically, learning is the formation of new synapses and dendrite branching (Zull 2002). "Teachers will do well if they think seriously about how to engage the emotion centers in the brain…The real challenge is to find methods that make emotion part of the meaning. Learning is best when it truly matters in a person's life, when he believes it is important" (Zull 2002, 226).

In the book, "Culturally Responsive Teaching and the Brain", Zaretta Hammond (2015) linked cognitive science research to the classroom learning experience through the lens of culture-based teaching. She argues that the achievement gap can be closed by these insights, "Building brain power is the missing link to closing the achievement gap for underperforming culturally and linguistically diverse students" (2015, 3). Hammond uses an analogy of a tree to explain culture. There are three distinct parts to the 'culture tree'. First, the 'surface culture' which contains observable patterns and a low emotional impact on trust (food, dress, music, holidays, etc.). Second, the 'shallow culture' which are the unspoken rules around social interaction and norms (eye contact, nonverbal communication, appropriate touching, etc.) and contain a high emotional impact on trust. Third is the 'deep culture' or the collective unconscious assumptions that govern worldview contained in every culture. Interactions at this final level are deeply emotional and have an intense emotional impact on trust (Hammond 2015).

In addition to culture being defined on three levels Hammonds points out important differences in two cultural archetypes: group orientation and communication. Hammond argues that most

Western European cultures came from an individualistic mindset, whereas most Indigenous mindsets were collectively based. One study from 2010 showed that approximately 20% of the world has an individualistic culture and the other 80% of the world's societies have a collective culture (Hoftede, Hofstede, and Minkov 2010). Geert Hoftede et al. created the "Cultural Dimensions Index" which used methods based in cultural psychology to create and evaluate countries on a 100-point scale where the higher the score, the more individualistic the society. The United States, Australia, and the United Kingdom were ranked the most individualistic societies in the world at scores of 91, 90, and 89. In comparison countries like Panama, Ecuador, and Guatemala were ranked most collective at 11, 8, and 6 (Hoftede, Hofstede, and Minkov 2010). In addition, the second archetype identified by Hammond to be significantly different between groups is communication traditions. Indigenous cultures are oral cultures where a larger emphasis is placed on relationships "because the process connects the speaker and listener in a communal experience" (2015, 28). There is an important connection between oral tradition and the community experience. Everyone is part of it. Everyone participates. Hammond argues that in the written tradition text takes the place of person-to-person interaction, more emphasis is placed on the printed dialog. These two points are relevant because oral tradition relies more heavily on memory and relationships; and collectivism aligns more closely with human evolution and survival (Eyler 2018). Most students of color come from community-oriented cultures, their brains more easily process information orally and actively. Both oral communication and collaborative learning are culturally responsive teaching (CRT) methodologies. Thus, the brain research is supporting the methods and efficacy of culturally responsive pedagogies (CRP).

Hammond takes the link between the cognitive science and culturally responsive teaching one step further. She explains the architecture of the brain in three parts: the reptilian region, the limbic region, and the neocortex region: (1) The 'reptilian region' is 500 million years old, made up of the brainstem, the cerebellum, and the reticular activating system (RAS) that controls alertness and attention. The reptilian region keeps the body functioning to stay alive. (2) The 'limbic region' is only found in mammals, it links emotions, behavior, cognition (Zull 2002). This part of the brain records memories. Within the limbic region three structures help maintain memory and emotion: the thalamus, the hippocampus and the amygdala. While the hippocampus houses the memory system, the amygdala is an almond-shaped structure that reacts to social or physical threat. When a threat happens, the amygdala sends a signal directly to the reptilian region to stop all other cognitive functions and the brain goes into 'fight or flight' mode. (3) The 'neocortex region' is the command center of the brain, the newest part that controls "planning, abstract thinking, organization, self-regulation, and imagination" (Hammond 2015, 40). This is where the higher learning happens. "….here in the neocortex…we have the chance to build our brain power, also called our intellectual capacity. The challenge is getting past the lower brain's two emotional gatekeepers: the reticular activating system (RAS) and the amygdala" (Hammond 2015, 41). Hammond argues that when students of color experience classrooms that are hostile the amygdala in the brain sends a distress signal to the body that "make(s) learning nearly impossible. Even if the environment isn't hostile but simply unwelcoming, the brain doesn't produce enough oxytocin and begins to experience anxiety" (Hammond 2015, 45). According to Hammond, the disparity in achievement between the majority and the minority groups is in part due to the lack of positive emotional experiences and lack of community in the classrooms that can cause the student of color to be stressed enough so that the brain shuts down higher order functions, thus decreasing learning (Hammond 2015; Madrazo and Motz 2005; Jensen 2005).

According to Hammond relationships are the key, the precursor to learning.

> *The brain needs to be part of a caring social community to maximize its sense of well-being. Marginalized students' needs to feel affirmed and included as valued members of a learning community….Our goal is to help alertness-that combination of excitement and anticipation we call engagement…every day.* (Hammond 2015, 47)

It is interesting and relevant that the human brain seems to be wired for the type of learning that is rooted in oral tradition, relationship, participation, and community. These are qualities of Indigenous knowledge systems (IKS). We can see that these approaches were previously mentioned in the study of Minnesota teachers of Native youth by Cleary and Peacock (1998) and similarly in the Arizona study by Castagno and Brayboy (2008). See Table 3 under 'Learning Styles for Indigenous Youth'.

3.2.2.3 Perceptions of Culturally Responsive Pedagogy (CRP)

What are students' perspectives of culturally responsive pedagogy (CRP)? Although much has been written on the theory and qualities of culturally relevant pedagogy (since Ladson-Billings coined the phrase in 1995) and culturally responsive teaching (since Gay coined the phrase in 2000), there is a limited number of empirically-based studies measuring the effectiveness of increased culturally relevancy/responsiveness, and in particular the efficacy of CRP and CRT from the students' perspective (Byrd 2016).

In 2001 Howard published a study that examined African-American students' perceptions of the pedagogical practices of culturally responsive teaching. The qualitative data from the student interviews was found to have three key themes:

1. Caring. The attribute mentioned the most frequently by the students was teachers' willingness to care about them. Teachers who practiced positive reinforcement, high expectations, and a sincere commitment to students' academic success were greatly preferred
2. Establish Community. Strategies that emphasized and reinforced a community-like or family-like learning environment were the second most frequently mentioned practice by students. Students were given the opportunity to develop social relationships and build community through various classroom traditions or simple rituals
3. Engaging classroom environments. The third most frequently mentioned attribute was the teachers ability to make learning "a fun and exciting process". Students reiterated the importance of "not being bored" and teachers who could create stimulating and exciting classrooms (Howard 2001, 144).

Based on this study and related research, Tyrone Howard (2003) suggested critical reflection practices for teachers as a precursor to implementing culturally relevant teaching. Statistically, at that time in 1998, African-American and Latinos made up 28% of the U.S public school K-12 enrollment. During the 1998-1999 school year African-American and Latinos students represented nearly 50% of all students labeled as mentally retarded, nearly 40% of all students identified as developmentally delayed and approximately 37% of all student classified as emotionally disturbed (U.S. Department of Education 1999). Howard outlines three components of the teachers' critical examination of race and culture: (1) teachers should acknowledge traditional school teaching includes a 'deficit-based' notion of diverse students; (2) recognize the definite connection between culture and learning and see students' cultural capital as an asset; and (3) acknowledge that traditional teaching reflects the culture of middle-class, European-American values and to combat this teachers should seek a "wider range of dynamic and fluid teaching practices" (Howard 2003, 198). Howard states that the tool of critical reflection for teachers is the key to embracing culturally responsive teaching (CRT) and "reversing the perennial underachievement that has become commonplace for an increasing number of students…Given the current cultural and racial demographics of our schools and society, the stakes we face as a profession and as a nation are too high to fail in this endeavor" (Howard 2003, 201).

A study in 2016 by Christy Byrd surveyed over 300 students nationwide in grades six through twelve. The ethnic makeup of the participants was equally distributed: White, Latino, African-American, and Asian (25% each group). The study focuses on the following question: How are students' perceptions of teachers' use of culturally responsive teaching and school racial socialization related to students' academic outcomes and racial attitudes? Two assessment tools were used to create the main survey. First, "The Student Measure of Culturally Responsive Teaching" (Dickson, Chun, and Fernandez 2016) was used to gauge culturally responsive teaching (CRT), (such as innovative methods using real-life examples), and cultural engagement (meaning the connection of student's culture and home-life into the class). And second, a new tool called "The School Climate for Diversity Scale-Secondary" was developed by Byrd (2016, 3). Academic outcomes, interest, and belonging were measured by self-reported answers to Likert-style questions such as: 'The grades I usually get in school', 'I find school interesting', and 'I really like people at my school'. The study found that student perceptions of the teacher using more constructivist practices was related to greater interest in school and a greater sense of belonging. Teachers were recommended to build relationships, humanize instruction, and teach with a sociopolitical consciousness (Byrd 2016).

What do college students in a teacher-education program working on attaining their teaching credentials (i.e. pre-service teachers) think of CRP? Kamau Siwatu (2007) developed an instrument to measure pre-service teachers' attitudes and abilities surrounding culturally responsive pedagogy. The new measures were called, "Culturally Responsive Teaching Self-Efficacy (CRTSE)" and "Culturally Responsive Teaching Outcome Expectancy (CRTOE)". Previous research had been done by Albert Bandura and Richard Walters (1977) and others showing that 'self-efficacy', or the belief in one's ability execute a specific task, was an accurate predictor of future actions. In addition, 'outcome expectations' has to do with a person's understanding of likely consequences of certain actions (Bandura 1978). Siwatu found that pre-service teachers' self-efficacy was highest for "helping students feel like important members of the classroom" and "develop a personal relationship with my students" (Siwatu 2007, 1092). In addition, preserve teachers' outcome expectations was highest for "a positive teacher-student relationship can be established by building a sense of trust in my students" (Siwatu 2007, 1092). Interestingly, the lowest ranked item in outcome expectations for the teacher candidates was "encouraging students to use their Native language will help to maintain students' cultural identity" (Siwatu 2007, 1092).

In a study of 55 pre-service elementary teachers by Barbara Frye et al. (2010) it was found that the teacher candidates gained knowledge and skill in understanding and practicing culturally responsive pedagogy during the semester-long methods course. Four faculty members administered an adapted version of Siwatu's (2007) "Culturally Responsive Teaching Self-Efficacy (CRTSE)" and "Culturally Responsive Teaching Outcome Expectancy (CRTOE)" measurement tools. History, literacy, and art were integrated into the course and then taught in an elementary classroom as a way to increase culturally responsive pedagogy (CRP). Pre-service teachers perceived that their knowledge level and teaching abilities of CRP would improve after the sixteen-week semester. Between the pretest and the posttest there was in fact a 50% increase in both the self-efficacy and the outcome expectations as indicated by the CRTSE and the CRTOE self-surveys (Frye et al. 2010). Although this study was limited in that it involved only one methods course, these results align with Bandura's earlier work and indicate that since the teacher candidates' beliefs in their own abilities surrounding CRP increased, it is more likely that they will use CRP in their future classrooms. Furthermore, the pre-service teachers' confidence in developing relationships with their future students is promising because research on CRT indicates this as a critical component of learning (Wlodkowski and Ginsberg 1995; Brown 2007; Bennett 2008).

One study of cultural diversity awareness by Melody and Jared Russell (2014) surveyed 35 pre-service science teachers using "The Cultural Diversity Awareness Inventory" (CDAI) first developed by Henry (1986; 1991). Participants were students at a southeastern U.S. university enrolled in a secondary science education program, 63% female and 94% white (one African-American student and one Asian student). The CDAI responses resulted in the following outcomes: the majority of pre-service science teachers did not think that their culture was different from the students they served; nearly half (46%) disagreed with identifying students by ethnic group; and slightly more than half of the students (51%) did not feel comfortable with people who spoke non-standard English (Russell and Russell 2014). These findings concur with the importance of addressing the façade of 'colorblindness' in the classroom (Ullucci and Battey 2011; Milner 2010; Liggett and Finley 2009; Cochran-Smith 1995). As stated by the authors of this particular CDAI study:

> *When students from the majority do not consider they are different or describe differences in their students this perpetuates the hidden curriculum and denies how culture or race/ethnicity impact perceptions. Lack of acknowledgement of student culture…can inadvertently promote negative stereotypes for certain students (e.g. African American, Latino/a) typically underrepresented in STEM areas.* (Russell and Russell 2014, 11)

Additionally, the study recommends that teacher education programs (TEP) for pre-service teachers in STEM, implement more emphasis addressing pre-service science teachers' level of comfort with language diversity and the importance of supporting students in light of the challenges of bilingual students in science.

3.2.2.4 State Standards and Culturally Responsive Pedagogy (CRP)

To what extent have schools implemented CRP within their state standards? Margaret Crocco and Arthur Costigan (2007) interviewed 200 teachers in New York City to gain a better understanding of the consequences of increased emphasis on testing and accountability as associated with the Elementary and Secondary Education Act called, "No Child Left Behind (NCLB)" (U.S. Congress 2001). Teachers are challenged with the added pressures of high-stakes testing and more time is focused on reading and math, and less time on other subjects, called "narrowing of curriculum" (King and Zucker 2005; Jerald 2006; Dillon 2006). Schools that test below grade level were most effected. Results showed that 'curriculum narrowing' has had a negative effect on teachers perception of their teaching practice, their professional growth, and their ability to develop relationships with students (Crocco and Costigan 2007). "…they consider the development of caring personal relationships with their students as essential to fulfilling their mission" (Crocco and Costigan 2007, 524). As one teacher explained, "Success in making these connections and getting to know students well regularly surfaced as a huge part of my job satisfaction" (Crocco and Costigan 2007, 524). Some researchers argue that culturally responsive pedagogy (CRP) and culturally responsive teaching (CRT) have been marginalized due to the increasing use of the business model on educational institutions and legislation like NCLB (2001). Christine Sleeter (2012) argues that there are three clear reasons why culturally responsive teaching (CRT) has been marginalized: (1) CRP is misunderstood as limited and superficial. For example, focusing on cultural holidays, food, dress, and/or assuming a homogenous, unchanging, group. (2) There is too little research showing a connection between achievement gains and CRP. In addition, more research is needed on the effects of CRP professional development for teachers and how this impacts their students. (3) Teachers fear of political backlash. Sleeter states that neoliberalism has influenced school reforms in a way emphasizes standardization and decontextualization but also, "…that frame education as both a commodity for individual economic advancement and a tool to shape workers for the global economy" (Sleeter 2012, 577). Gutierrez et al. (2002, 335) found that teachers believe it is "professionally and, in some cases legally, risky" to engage in culturally responsive teaching that conflicts with the status quo.

In the U.S each state regulates what teachers should know and should be able to do, called the 'professional teaching standards'. Yet, at the national level there are two models that have a strong impact on the state standards: the Interstate New Teacher Assessment and Support Consortium (InTASC) and the National Board for Professional Teaching Standards (NBPTS). In 2011 the Interstate New Teacher Assessment and Support Consortium (InTASC) created the "Model Core Teaching Standards" which define what all teachers should know and what they should do in order to "ensure every K-12 student reaches the goal of being ready to enter college or the workforce" (InTASC 2011, 3). The report has a strong focus on general CRP behaviors such as: respect for all cultures, classroom instruction that relates to the students' cultures, and avoiding personal bias. The revised 2013 version specifically states:

> *Teachers need to recognize that all learners bring to their learning varying experiences, abilities, talents, and prior learning, as well as language, culture, and family and community values that are assets that can be used to promote their learning. To do this effectively, teachers must have a deeper understanding of their own frames of reference (e.g., culture, gender, language, abilities, ways of knowing), the potential biases in these frames, and their impact on expectations for and relationships with learners and their families.* (InTASC 2013, 4)

One of the ten standards reinforce this CRP-aligned goal, "Standard #2: Learning Differences. The teacher uses understanding of individual differences and diverse cultures and communities to ensure inclusive learning environments that enable each learner to meet high standards." (InTASC 2011, 8). In addition, the national accreditation board for teachers, Council for the Accreditation of Educator Preparation (CAEP), has endorsed the InTASC "Model Core Teaching

Standards" so that all CAEP accredited teacher education programs are aligned with these goals. The National Board for Professional Teaching Standards (NBPTS) has also informed the development of state standards. Developed in 1997, these are voluntary assessment standards that are meant for experienced educators who meet high board standards. Based on five core propositions, CRP-alignment is seen in Core-Five, "Teachers are Members of Learning Communities". Here it states:

> *Accomplished educators encourage students to appreciate linguistic traditions and ethnic contributions, to study social influences on their expectations and aspirations, and to discuss the effects that economic conditions can have on political views and outlooks. Although careful attention to diversity may challenge teachers, learning about a wealth of cultures can help them work meaningfully with students. An understanding of multiculturalism promotes an acknowledgment of differences and similarities, which, in turn, inspires students to accept individuals and to adopt civic ideals. Accomplished teachers capitalize on those opportunities so they can respond productively to their students' diverse backgrounds.* (NBPTS 2016, 39)

In 2019 the New America Foundation conducted a study of fifty states in the U.S. in order to determine the scale at which states are including CRT competencies in their professional teaching standards. Using research in CRP, Jenny Munoz et al. (2019) developed eight cultural competencies to measure the schools' effectiveness across all grade levels and subject areas: (1) Reflect on one's cultural lens, (2) Recognize and redress bias in the system, (3) Draw on students' culture to shape curriculum and instruction, (4) Bring real-world issues into the classroom, (5) Model high expectations for all students, (6) Promote respect for student differences, (7) Collaborate with families and the local community, and (8) Communicate in linguistically and culturally responsive ways. It was found that all states are including CRP competencies in their standards, but there were three recommendations given in the report. First, revise teaching standards to articulate the eight cultural competencies (listed above). Second, create a continuum of teaching practice to assess quality teaching at different levels. And third, design and offer ongoing professional development for teachers' so that CRP can be supported (Munoz 2019). The states with the highest level of support for CRP and CRT were found to be Alaska and Washington State. Both states developed and implemented a set of stand-alone standards for culturally responsive teaching that are intended to reach all teachers.

3.2.2.5 STEM Examples of Culturally Responsive Pedagogy (CRP)

There are many empirical studies that document how culturally responsive teaching (CRT) in K-12 classrooms positively effects students' academic achievement and attitudes, especially in urban environments (Dickson, Chun, and Fernandez 2016; Bergeron 2008; Brown 2007). Most relevant to this study is the question: to what extent has culturally responsive pedagogy in STEM been implemented in higher education?

An article published by the International Council of the Association for Science Education (ICASE) "Engaging Students in STEM Education" (Garza 2009) urged K-12 schools and institutions of higher education to work together "to develop pedagogical models that provide rigorous, well-rounded education and outstanding STEM instruction" (Kennedy and Odell 2014).

Specifically stated as one of the ways conventional approaches must be altered seen in the following statement:

> *STEM educators must provide students with interdisciplinary, interdisciplinary, multicultural, and multi-perspective viewpoints to demonstrate how STEM transcends national boundaries providing students a global perspective that links students with a broader STEM community and workforce.* (Kennedy and Odell 2014, 256)

A call for change is directed towards teachers. In a publication by Abiola Farinde and Chance Lewis (2012) the dual effects of race and gender facing African American females entering into STEM are examined. By comparing data from the National Assessment of Educational Progress, College Board and the Baccalaureate and Beyond Longitudinal Study (U.S. Department of Education, 2011), African American female students were "uncompetitive and lack needed skills in the area of math and science" (Farinde and Lewis 2012, 428). They argue that urgent changes need to occur at the primary level. Recommendations were aimed at teachers as the primary influencers of change and included: holding equitable academic standards, continual encouragement, equal engagement across gender, hands on active cooperative learning, and "teachers should infuse culturally relevant teaching strategies into math/science instruction" (Farinde and Lewis 2012, 429).

An example of culture-based teaching and strategies in STEM was published by Jacqueline Leonard (2008) called, "Culturally Specific Pedagogy in the Mathematics Classroom: Strategies for Teachers of Diverse Students". This resource book provides K-12 teachers with a conceptual overview of CRP and curricular resources. Leonard encourages educators to use culturally specific pedagogy "for teaching mathematics in a way that combats and confronts the forms of oppression that students face today" (Leonard 2008, i). Leonard uses the term, 'culturally specific pedagogy (CSP)', to emphasize a combined framework of critical race theory (CRT) with Black Feminist Theory (BFT) in order "to function as (a) means to empower students of color and females to overcome the oppression of Euro-American mathematics" (Leonard 2008, 7). Educational approaches of culturally specific mathematics presented by Leonard include: computational thinking, computer scaffolding, game design, robotics, and spatial ability. For example, the 'Space Links' program was implemented by Leonard. Here female and minority pre-service teachers were offered internships with NASA scientists in order to foster greater motivation and enthusiasm in the students (Leonard 2008).

First Nations Canadian efforts to advance pluralist, culturally responsive, education pedagogy have found growing momentum since the Truth and Reconciliation Commission (TRC) of 2016. One leader in culture-based school science and mathematics reform is Aikenhead at the Aboriginal Education Research Centre based at the University of Saskatchewan. In a 2017 publication Aikenhead recognizes that mathematics is one of the largest barriers to graduation for First Nations students. He goes on to explain that "Mathematics is a human invention", and that "Every major culture has developed its own mathematics system in tandem with their everyday cultural activities…" (Aikenhead 2017a, 564). The conventional mathematics taught in the school systems today was directly established for the formal, elite, population of British culture. Mathematics "we teach today is really Euro-American mathematics", he explains (Aikenhead 2017a, 567). Aikenhead points to Plato's binary understanding of ideas, either ideas were abstract or they related to the everyday. The subject of mathematics became split and during the European Renaissance the abstract version of mathematics became the prevailing approach. This separation of mathematical ideas from human experience and culture is still reigning in today's schools. After recognizing the cultural roots of mathematics Aikenhead points out that this instructional method was always intended to serve only the top 24% of the population, and now in the 21st century, it is no longer acceptable to leave out the remaining 76% of the population. He goes on to state that in addition to the curriculum reform, the low Indigenous STEM enrollment is the fault of STEM departments because, "the rate at which university STEM students leave the STEM pipeline is *twice* that of high schools. The problem to be fixed is how students are treated in university STEM programs" (Aikenhead 2017a, 566).

As a self-disclosed, non-Indigenous, STEM scholar and researcher, Aikenhead has written extensively of a 'Path to Reconciliation' where he urges educators to: (1) critically analyze conventional mathematics curriculum and to consider "which ones should be updated because they interfere with the engagement and achievement of most Indigenous students and a majority of non-Indigenous students" (Aikenhead 2017b, 73); and (2) identify tangible ways that math is part of mainstream and Indigenous cultures and create resources to promote academic achievement and reconciliation. The major research and development agenda according to Aikenhead is: to explore culturally responsive teaching (or place-based teaching); to examine conventional curricula for cultural biases; to promote culturally relevant teacher professional development; to create culturally specific resources (Aikenhead 2017b). In 2010, the Saskatchewan Ministry of Education published a grades 3-9 science textbook that includes the Indigenous perspective alongside the European science perspective (Aikenhead and Michell 2011), and in 2014 a professional development resource guide for supporting culturally responsive science teaching was published (Aikenhead et al. 2014). Chapter themes include topics like, 'Benefits from interacting with Elders and Knowledge Keepers', 'Connect to the Land and Nurture Self-Identities', 'Culturally Valid Assessment', 'The Brain needs the Heart', and 'Teaching as Storytelling'.

An emerging aspect of culturally responsive pedagogy is the notion of 'care-based education'. In an article by Rae Shevalier and Barbara McKenzie 2012, it is advocated that it is inadequate to simply give teachers the 'how' and 'what' of culturally responsive teaching is without the in-depth discussion of the 'why' it is needed.

> *…we reject the deficit models of thinking that imply students who are not able-bodied, heterosexual middle-class English speaking adherents of European American culture primarily complicate educational processes and drain resources. Instead, we argue that cultural and linguistic diversity is a valuable resource in urban schools and that teachers who combine culturally responsive teaching practices with care, ethics-based approaches have the means to do 'a far better job' of educating our urban students.* (Shevalier and McKenzie 2012, 1087)

The idea of care-based theory was introduced by Nel Noddings (1984) where a critical distinction is made between 'caring about' and 'caring for' students in an educational setting. The idea is that "caring about" someone is a more emotionally detached, abstract activity that is not sustainable in the long run. The better approach is to 'care for' a student which is a deeper, face-to-face, authentic relationship with the student that communicates the desire to help and takes action (Noddings 2002). Pre-service teachers and McKenzie state, "The point of culturally responsive teaching is to *respond* to students in ways that build and sustain meaningful positive relationships" (Shevalier and McKenzie 2012, 1091). Four components of moral education are outlined as follows: (1) modeling, (2) dialogue, (3) practice, and (4) confirmation (Noddings 2002). In addition to the academic achievement, Shevalier and McKenzie argue that culturally responsive teaching makes a difference in terms of "social and emotional growth and empowerment" of students in urban school settings (Shevalier and McKenzie 2012, 1102).

In the higher education landscape, there are relatively few published examples of culturally responsive pedagogy (CRP) in STEM. One example is the work done by Christopher Jett at the University of West Georgia in culturally responsive college mathematics (Jett 2013). Here Jett explicitly uses the frameworks of culturally relevant pedagogy (Ladson-Billings 1995b) and culturally responsive teaching (Gay 2010) when teaching undergraduate mathematics courses. By using strategies and assumptions of "mathematically competent cultural beings" and "brilliance discourse", he deliberately attempts to "empower students to take hold of and internalize positive affirmations concerning their mathematical abilities" (Jett 2013, 110). Jett recognizes the on-going efforts made to implement culturally relevant teaching for pre-service teachers but adds, "…[there is] very little being done at the collegiate level to make mathematic culturally specific to the needs of African American students…'true' culturally responsive mathematics pedagogies are rare" (Jett 2013, 111).

Barriers for implementing culturally responsive pedagogy in higher education are similar to those expressed in implementation of active learning approaches. One study in Health Science entitled, "I Would Teach It, But I Don't Know How", surveyed over 100 faculty regarding their perceptions of cultural competency training. It was found that most faculty supported the training of students because intercultural skills were deemed valuable for future employment. The problem identified was that the faculty themselves felt a lack of skill and knowledge to teach cultural competency, and how to evaluate the effectiveness (Young and Ramírez 2017). Despite the chilly climate and lack of diversity in STEM and health sciences for students, the Young and Ramirez study found that there was also a lack of cultural competency training for the faculty. Especially interesting and relevant, faculty respondents cited a 'culture of no culture' bias in the health sciences. This is the idea that medical knowledge is more authentic and real, whereas the patient's knowledge is perceived as 'cultural'. Another study at a large Midwest university surveyed over 200 faculty in regard to multicultural teaching and found the unmistakable result, "The most commonly expressed barrier to multicultural teaching was their anticipation of student resistance" (Bigatti et al. 2012, 84).

Chapter Four: Research Methodology

4.1 Study Design

This research study explored how different students respond to a course intervention that emphasizes increased culturally responsive pedagogy. In this study, student performance was measured by two key factors: science content knowledge and classroom engagement. The hypothesis of this research study was that students in the course with increased cultural responsiveness (CR) will show greater learning gains and increased engagement as compared to the students in the interactive engagement only (IE) course. Additionally, underrepresented minority (URM) students in the course with increased cultural responsiveness (CR) will show greater gains as compared to their counterparts in the interactive engagement only (IE) course.

The primary goal of this research was to answer the question:

To what extent will ASTR 101 students, particularly underrepresented minority[2](URM) groups in STEM, be more engaged and show positive learning gains when culturally inclusive content and culturally responsive instructional strategies are implemented as opposed to active learning engagement pedagogy?

Three key questions that were examined:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*
- *How does culturally inclusive curriculum qualitatively and quantitatively affect knowledge acquisition for ASTR 101 students?*
- *Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?*

Instructional materials in the IE course were procured in alignment with a widely published introductory astronomy textbook (Palen et al. 2014). Active learning activities were compiled from the Center for Astronomy Education (CAE) (2016) or the textbook resources with varying degrees of modification. In addition, the IE course had weekly labs where only 20 students met in designated lab room. Regular lectures that followed the textbook topics were implemented on a weekly basis. Class meetings were M-W-F during the semester in a fixed seating classroom of 60 students. The IE course did not include any intentional culturally responsive (CR) instructional materials or approach.

The course taught with increased cultural responsiveness, the (CR) course, was similar to the interactive engagement (IE) course, in that active learning was regularly implemented, the class met M-W-F during a semester format, in a large lecture, fixed seating auditorium classroom of 200 students. Labs were not part of the CR course. The principal difference in the CR course as compared to the IE course was that the CR course included regular approaches and content with increased culturally responsive pedagogy (CRP). Sample CR activities involved: discussions, (both large group and small group formats, that occurred in class and at home), critical thinking

[2] Underrepresented minority (URM) students are defined as: African-American, Hispanic-American, Native American, Africa (not American), and Multicultural. The category of non-underrepresented (non-URM) student is defined as: White non-Hispanic, Asian-American, and Asian (not American).

exercises, current night sky activities that included uniquely designed star maps, lab-like data collecting activities, and a photo gallery for each of the four class segments. Culturally responsive activities were designed by the author of this research study. See Appendix E-Sample Curriculum.

Table 4 - Classes involved in this study

	Semester	Enrollment
IE course 1	Fall 2018	59
CR course 1	Fall 2018	171
IE course 2	Spring 2019	59
CR course 2	Spring 2019	169

Statistical tests used here included correlation tests and comparison of the means tests. Correlational tests used in this study included: Pearson correlation (strength of the association between two normally distributed or parametric variables), Spearman correlation (strength of the association between two ordinal, non-parametric data sets, i.e. does not assume a normally distributed data set), or Chi-square correlation (strength of the association between two categorical variables). Comparison of the Means tests used in this study included: Paired T-test (difference between two parametric variables), Ranked T-test (difference between two non-parametric variables), and Analysis of Variation (ANOVA) tests (difference between group means for more than two groups after data has been transformed to a parametric or normal distribution).

Depending on the specifics of each data set, (number of groups, time points, data distribution-normal or non-normal, variable type-ordinal or categorical), one of the above statistical tests was used for the analysis. In any case, the primary result of the statistical analysis gives a 'p-value' which is a measure of whether the relationship between the variables is real or random. This study used a p-value of 0.05 or less, meaning that for a relationship to be 'statistically significant' there must be no more than a 5% chance that the results were simply random. This is based on a level of 95% confidence. When the p-value is less than 0.05, it is also the said that the null hypothesis, (that there is no effect, no relationship), is rejected and the variables are in fact dependent (i.e. there is an effect, a relationship between the variables).

When T-tests were used, a second statistical measure was implemented in this study called the 'effect size'. The effect size measures the strength or the magnitude of the relationship of the variables taking into account the sample size. In some cases where there is a large sample size just using the p-value alone could produce a statistically significant result but of a small effect size and therefore it is not meaningful. In this case, when examining the data sets for a dependent relationship between the variables, there are two relevant criteria: (1) the p-value must be less than 0.05, and (2) the effect size would be large.

Contingency tables (or crosstabs) were used in this study when the data sets were categorical. For example, when testing for a correlation between course grade, course structure, and URM status, a contingency table would be used for the analysis and a Chi-squared test would be run on the data. If the test produces a p-value less than 0.05, then a statistically significant relationship has been measured. If the p-value is less than 0.01 the results are held to be 'very statistically significant'.

4.2 Measurement of Science Content Learning Gains

To measure science content learning gains, two sources of data, course grades and learning gains on the Astronomy Diagnostic Test (ADT) concept inventory, were statistically examined to locate correlations and ultimately address two of the three key questions:

- *How does culturally inclusive curriculum quantitatively affect knowledge acquisition for ASTR 101 students?*
- *Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?*

4.2.1 Course Grades

The first method used to show the science content learning gains was course grades. This includes both the numerical final course grade and the letter grade equivalent. Grades were defined as follows: 100 to 90% is an 'A', 89 to 80% is a 'B', 79 to 70% is a 'C', 69-60% is a 'D', 59 or lower is 'F'. Students that withdrew from the course received a 'W'. Demographic data of sex and ethnicity was gathered from the Astronomy Diagnostic Test (ADT). Ethnicity was further categorized into underrepresented minority (URM) status. For the purpose of this study, underrepresented minority (URM) students are defined as: African-American, Hispanic-American, Native American, African (not American), and Multicultural. The category of non-underrepresented (non-URM) student is defined as: White non-Hispanic, Asian-American, and Asian (not American). Note that in South Africa and other places the term 'race' is equivalent to the term used in the United States, which is 'ethnicity'.

Two-way and three-way contingency table analyses were used to evaluate the relationship between: course grades, course structure, URM status, and sex. In general, for each analysis, if the p-value was less than 0.01, then the null hypothesis (no effect, no correlation) was rejected and a link between the variables was confirmed, i.e. they are dependent variables. In the two-way analysis, course grades were paired with course structure, URM status, and sex to more clearly quantify the relationships. In the three-way analysis, course grades are measured simultaneously against course structure, URM status, and sex. The increasingly narrow statistical analysis allows for finer resolution of the data so that the key question, whether diverse students attained more science content knowledge through participating in the CR course can be definitively answered and quantified.

4.2.2 Astronomy Diagnostic Test (ADT)

The Astronomy Diagnostic Test (ADT) version 2.0 is a research-based assessment tool for introductory college-level astronomy courses for non-science majors that is intended to measure course effectiveness by comparing science content learning gains. The original version of the ADT was developed by a team of astronomers in 1998 who were concerned about improving STEM education. After multiple revisions the final version is called ADT version 2.0 (Hufnagel 2002; Deming 2002b). This pencil-and-paper test consists of 21 science-based content questions and 12 demographic or personal questions. All 33 questions are multiple choice. The ADT requires students to participate twice: once in a pre-course test and then in a post-course test. The test emphasizes concepts while avoiding scientific lingo. The development was largely based on: student interviews, open-ended student responses to early versions of the test questions, and critiques from astronomy faculty (Hufnagel 2002; Deming 2002b). After receiving National Science Foundation (NSF) funding in 2000 a national study was conducted to further confirm the reliability and validity of the ADT assessment tool. Over 5000 students in 97 different classes with 68 professors participated in the study, establishing the ADT v2.0 as a national database and the common standard for introductory astronomy college courses (Deming 2002b; Brogt et al. 2007; Zeilik 2002).

The second method used to measure science content learning gains was the concept inventory, the Astronomy Diagnostic Test (ADT). The pre-course and the post-course results were used to calculate the average normalized gain <g>.

$$< g > \equiv \frac{\% < S_f > \, - \% < S_i >}{100 - \% < S_i >}$$

Where $< S_f >$ and $< S_i >$ are final (post) and initial (pre) class averages (Hake 1998). Also used as an important measure in this study is the related average individual gain <g>$_{\text{Indiv}}$. The main difference is that the average individual normalized gain can be correlated more easily with other demographic variables. Two-way and three-way contingency table analyses were used to evaluate the relationship between: ADT normalized gain, course structure, URM status, and sex.

In this research study the ADT v2.0 was administered to all students in both the IE course and the CR course in both semesters. Participation included 415 students for the pre-test and 302 for the post-test. This represents a 73% return rate, which is consistent with the national ADT v2.0 database of a 72% return rate for pre-course test results and post-course test results (Deming 2002b).

The ADT v2.0 concept inventory served as a measurement tool for gain in astronomy-content conceptual knowledge. The topics covered on the ADT version 2.0 are as follows (Hufnagel 2002):

Table 5 - Topics on the ADT v2.0 (Hufnagel 2002)

Content Covered on ADT	IE course	CR course
Apparent motion of the Sun	✓	✓
Scale of the Solar System	✓	✓
Phases of the Moon	✓	✓
Linear distance scales	✓	✓
Seasons	✓	✓
Global warming	✓	
Nature of light	✓	✓
Gravity	✓	✓
Stars	✓	✓
Cosmology		✓

4.3 Measurement of Engagement Gains

The instruments used to measure engagement gains were the following: classroom observation; student survey data; and student interviews.

The above tools seek to answer all three of the key questions:
- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*
- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?*
- *Will underrepresented minority students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?*

Three instruments are used here to more effectively measure engagement in a mixed-method quantitative analysis of qualitative data. As can be seen in the table below, each instrument can address and give quantifiable results for particular key questions. The COPUS observational tool and the anonymous student surveys will address the first two questions only. Student interview data will speak to all three key questions.

Table 5 - Engagement gains as indicated by three key questions, as measure by three different instruments

	COPUS	Surveys	Interviews
Will students find ASTR 101 more engaging if the content is more culturally relevant	✓	✓	✓
How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students	✓	✓	✓
Will underrepresented minority students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy			✓

4.3.1 Classroom Observation Using COPUS

Science faculty from University of Maine in collaboration with faculty from University of British Columbia in Vancouver created a classroom observational protocol to collect information about STEM teaching practices specifically in the classroom to support institutional change. The Classroom Observation Protocol for Undergraduate STEM (COPUS) was created in 2013 with the goals: (1) to characterize the general state of STEM teaching; (2) provide feedback to instructors; (3) identify professional development needs; (4) check the accuracy of faculty self-reporting (Smith et al. 2013b).

Existing observational protocols were found inadequate. For example, Reformed Teaching Observation Protocol (RTOP) involved multi-day training and observer-dependent judgements (Sawada et al. 2002; SERC 2011). Another protocol, Teaching Dimensions Observation Protocol (TDOP), involved recording classroom behavior at 2-minute intervals but due to 46 codes in six categories and a three-day training it was also not acceptable (Hora, Oleson, and Ferrare 2013).

The COPUS was adapted from TDOP but contains only 25 classification codes in two categories. Classroom observers keep track at 2-minute intervals: what the instructor is doing and what the students are doing. For example, observers record if the instructor is: lecturing, answering student questions, or moving through the classroom, etc. Observers at the same time intervals record if the students are: listening, working in groups, problem solving, etc. Training to achieve a high inter-rater reliability (IRR) requires only a few hours (Smith et al. 2013b). It is also worth noting, "COPUS captures the actions of both instructors and students, but does not attempt to judge the quality of those actions for enhancing learning" (Smith et al. 2013, 621). The COPUS measurement tool is widely accepted as the standard protocol for higher education in order to measure what is actually happening in the classroom (Lund et al. 2015; Arum et al. 2015; AAAS 2013).

1. Students are Doing	
L	Listening to instructor/taking notes, etc.
Ind	Individual thinking/problem solving. Only mark when an instructor explicitly asks students to think about a clicker question or another question/problem on their own.
CG	Discuss clicker question in groups of 2 or more students
WG	Working in groups on worksheet activity
OG	Other assigned group activity, such as responding to instructor question
AnQ	Student answering a question posed by the instructor with rest of class listening
SQ	Student asks question
WC	Engaged in whole class discussion by offering explanations, opinion, judgment, etc. to whole class, often facilitated by instructor
Prd	Making a prediction about the outcome of demo or experiment
SP	Presentation by student(s)
TQ	Test or quiz
W	Waiting (instructor late, working on fixing AV problems, instructor otherwise occupied, etc.)
O	Other – explain in comments

2. Instructor is Doing	
Lec	Lecturing (presenting content, deriving mathematical results, presenting a problem solution, etc.)
RtW	Real-time writing on board, doc. projector, etc. (often checked off along with Lec)
FUp	Follow-up/feedback on clicker question or activity to entire class
PQ	Posing non-clicker question to students (non-rhetorical)
CQ	Asking a clicker question (mark the entire time the instructor is using a clicker question, not just when first asked)
AnQ	Listening to and answering student questions with entire class listening
MG	Moving through class guiding ongoing student work during active learning task
1o1	One-on-one extended discussion with one or a few individuals, not paying attention to the rest of the class (can be along with MG or AnQ)
D/V	Showing or conducting a demo, experiment, simulation, video, or animation
Adm	Administration (assign homework, return tests, etc.)
W	Waiting when there is an opportunity for an instructor to be interacting with or observing/listening to student or group activities and the instructor is not doing so
O	Other – explain in comments

Figure 15 - COPUS original codes, 25 total in two categories; 13 student codes plus 12 instructor codes (Smith et al. 2013b)

Prior to the actual classroom observations, training of three observers using the COPUS method was carried out by a professional evaluator and science education specialist with over three decades of experience. Observers first became familiar with the codes, then observers were asked to code practice videos at 2-minute interval using the COPUS protocol. Observers practiced on STEM teaching videos of different lengths, 2-minute, 8-minute, and 10-minute. Videos were paused every 2 minutes and the group discussed their results. Observers took turns stating what codes were used for both the instructor and students in the practice videos. As practice videos became progressively more challenging to code, any discrepancies were discussed in detail. A refresher training was implemented between semesters to review and update the observers.

The COPUS observing of ASTR 101 IE and CR courses was implemented in Fall semester 2018 and Spring semester of 2019. Each course had six observations approximately equally spaced throughout the semester.

Table 6 - Information on the courses observed using COPUS

	Semester	Number of classes observed	Enrollment
IE course 1	Fall 2018	6	59
CR course 1	Fall 2018	6	171
IE course 2	Spring 2019	6	59
CR course 2	Spring 2019	6	169

COPUS was modified in three ways: (1) codes related to clicker questions were not used because no clicker questions were used in any of the classes; (2) all observations were recorded at 1-minute intervals instead of the COPUS original design of 2-minute intervals; and (3) COPUS collapsed codes were implemented for all observations. Collapsed codes contain eight codes in two categories. Three professionally trained observers rotated observation sessions. See Appendix B- COPUS Observer's Coding Form (Smith et al. 2013b).

STUDENTS

R Receiving	L: Listening to instructor V: Viewing visuals
STC Talking to Class	AnQ: Student answering question posed by instructor SQ: Student asks question WC: Students engaged in whole-class discussion SP: Students presenting to entire class
SW Student Working	Ind: Individual thinking/problem solving WG: Working in groups on worksheet activity OG: Other assigned group activity Prd: Making a prediction about a demo or experiment TQ: Test or quiz
O Other	W: Waiting (instructor late, working on fixing technical problems) O: Other

FACULTY

P Presenting	Lec: Lecturing or presenting information RtW: Real-time writing D/V: Showing or conducting a demo, experiment, or simulation
G Guiding	FlUp: Follow-up/feedback on clicker question or activity PQ: Posing question to students (nonrhetorical) AnQ: Listening to and answering student questions to entire class MG: Moving through class guiding ongoing student work 1o1: One-on-one extended discussion with individual students
A Administration	Adm: Administration (assign homework, return tests, etc.)
O Other	W: Waiting (instructor late, working on fixing technical problems) O: Other

Figure 16 - COPUS observational codes. Collapsed codes on left; Individual codes on right

STUDENTS: **R**-Receiving, **STC**-Talking to Class, **SW**-Student Working, **O**-Other
FACULTY: **P**-Presenting, **G**-Guiding; **A**-Administration, **O**-Other

	Students				**Faculty**				**Engagement**			**Comments**
min	R	STC	SW	O	P	G	A	O	L	M	H	
1												
2												
3												
4												
5												

Figure 17 - An excerpt of the COPUS coding form Collapsed Codes used in this study. Observers place a checkmark in the box if the behavior occurs during the 1-minute segment. Multiple codes can be marked for the same time block (Smith et al. 2014b).

In addition to the recording of instructor and student behavior at 1-minute intervals throughout the 50-minute class time, level of engagement was also recorded in all courses. The coding of level of engagement is classified as follows: low (0-20% of the students engaged); medium (21-79% of the students engaged); or high (80-100% of the students engaged) (Smith et al. 2013b). Although engagement can be challenging for observers to determine consistently across multiple classroom observers (Smith et al. 2013b), in this study the same three observers were used to give a first order level of consistency for recording engagement in all twenty-four observing sessions. The observers were: two females and one male; Indigenous, White, and Asian by race/ethnicity; an upper-level undergraduate, a graduate student from another institution, and a professional educator. None of the details of this study, (including the title of the dissertation), were shared with the observers.

The COPUS tool was used to measure two of the three key questions:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*

- How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?

Various COPUS data analyses were performed:

(I) COPUS Profiles of course formats, 'pie chart analysis', for the IE course and the CR course, including behavior codes such as the amount of time student are R-Receiving and the amount of time the instructor was P-Presenting over the semester. For the traditional (T) science course or the IE course, these indicators, 'R' and 'P', should be higher percentages. A typical traditional (T) STEM college class comprises 50-75% lecture or instructors presenting-P (Smith et al. 2014b). Specifically in physics courses lectures account for approximately 60% of the class time (Lund et al. 2015).

(II) Analysis of observers recording of 'level of engagement' (low, medium, or high) for both the IE and the CR courses. Based on the hypothesis, it would be expected to see engagement in both courses since they both contain active engagement, (A) but higher level of engagement averages should be seen in the CR course.

(III) Quantification of the dependency or association of the statistical relationship between 'level of engagement' and the COPUS learning behavior codes using correlation analysis. The relevant question addressed here is, which behavior codes correlate most strongly with engagement? To do this COPUS observers data sheets were merged such that a checked box is equivalent to the numeric value '1', and an unchecked box is equivalent to the numeric value '0'. In this way for each one-minute class interval, any particular behavior could receive a value from 0 to 1. Next the two observers sheets were merged by summing the score for each behavior, for each one-minute interval. Level of engagement values were scored with low-1, medium-2 and high-3, then the two observers data sheets were merged. Engagement values ranged from 0 (lowest) to 6 (highest). The hypothesis was that students receiving-R and instructor presenting-P, will be inversely proportional to engagement. On the other hand, students working-SW, instructor guiding-G, and students talking-STC was expected to be strongly correlated to 'level of engagement'.

4.3.2 Student Surveys

The student surveys were used to measure two of the three key questions:

- Will students find ASTR 101 more engaging if the content is more culturally relevant?
- How does culturally inclusive curriculum qualitatively and quantitatively affect knowledge acquisition for ASTR 101 students?

Anonymous student satisfaction surveys were designed to measure classroom engagement and learning acquisition using professional software created by the experience management company, Qualtrics (Smith et al. 2014). Surveys were administered not more than twenty-four hours after selected class activities were completed. The survey hyperlink was posted in several accessible locations. Selected surveyed classes were approximately equally spaced throughout the semester. Extra credit was given to the entire class if there was a 40% or greater response rate. Overall there were twenty-eight surveys administered approximately half to the IE course and half to the CR class.

Surveys were chosen to be representative of all the various classroom designs: discussion, lab, activities, lectures, etc. Originally surveys developed in 2017 contained approximately twenty-five questions. Although items of the survey underwent modification between semesters, the general characteristics of the surveys remained consistent. The modified group of survey questions contained approximately fifteen questions. All questions were Likert scale quantitative questions and the last question was qualitative write-in question open for comments.

Table 7 - Surveys administered

	Semester	Number of classes surveyed	Enrollment
IE course 1	Fall 2018	7	59
CR course 1	Fall 2018	10	171
IE course 2	Spring 2019	6	59
CR course 2	Spring 2019	6	169

The survey contained questions focused around the following topics: (1) engagement; (2) knowledge acquisition and communication; (3) night sky; (4) science and society; (5) visual language and creativity; and (6) overall satisfaction. Engagement questions were developed using a modified version of a survey instrument created by The Science Learning Activation Lab-Measures Technical Brief-"Engagement in Science Learning Activities" (Chung et al. 2016). Survey questions related to the night sky were adapted from a cultural astronomy survey instrument called, "The Sky In Our Lives" (Holbrook 2008; Ndlovu 2016). Other reference surveys include "Astronomy Attitudes Survey" (Zeilik 2012). See Appendix C-Survey Instrument.

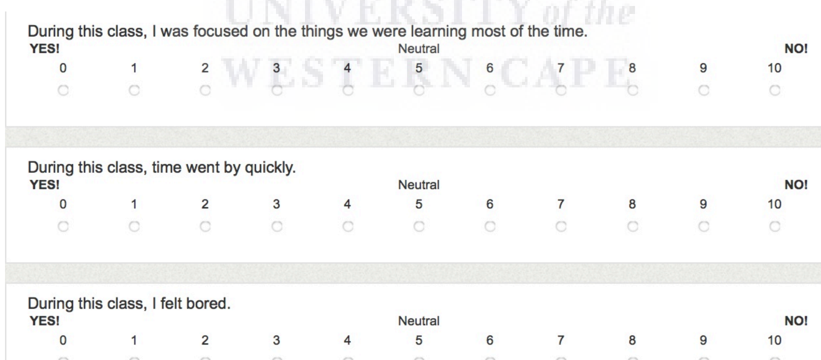


Figure 18 - Anonymous Student survey excerpt, engagement-type questions

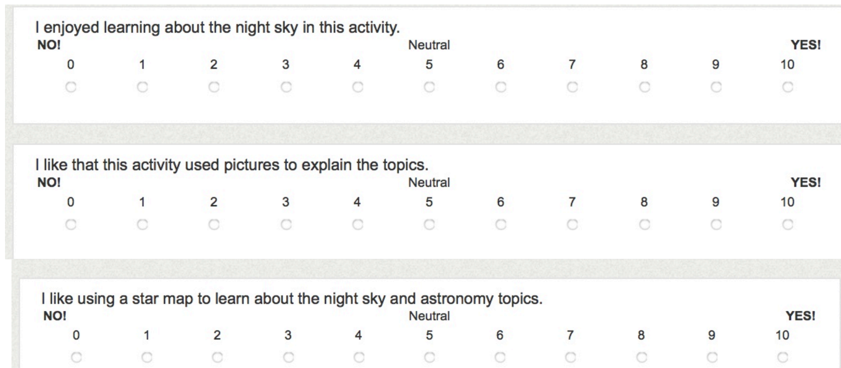


Figure 19 - Sample anonymous survey questions excerpt, night-sky type questions

The Survey Analysis Plan was as follows:

(1) Examine the distribution of the data to gain an overall understanding of trends, with focus on the engagement variables. Results will be visualized and summarized, interesting or surprising results will be noted.
(2) Measure co-relationships, to determine which of the apparent differences are actually statistically significant and to what degree.
(3) Statistical correlations will emphasize two different dependent (or key) variables: engagement and satisfaction in order to gain further insight into which of the remaining variables are the drivers of engagement and satisfaction.

The data in this study was ordinal, except for two questions that appeared near the end of the survey. The categorial question was, 'In general, I find astronomy', and the answer choices were: Very interesting, Interesting, Boring, Hate it. The other question was an open-ended text question, 'Any other comments?'.

4.3.3 Student Interviews

The student interviews were used to elicit data on personal perceptions, beliefs and experiences of the CR course relative to other courses. 'Down-the-pipeline' interviews were conducted with ten students. This term means that students needed to have completed an introductory astronomy course taught by the author of this research study and at least one other college class. Ideally they would be near graduation, and would have taken a large number of college classes. Potential students were recruited by the following methods: announcements made in class, a widget on the class webpage towards the end of the semester, and a class email. The purpose of the interviews was to compare the classroom experience and level of engagement in this particular ASTR 101 class to other college classes the student has taken. There were twelve questions in total. Questions dealt with class motivation, experiences within the class, interests, and expectations of the course. Additional questions were asked of the informants during discussion based on the individual direction of responses. This strategy gave the interviews more of a conversational tone and allowed for the investigation of related themes. Participants were interviewed for approximately twenty minutes and were semi-scripted to allow for student's voice to be heard and followed in a conversational manner. Audio recording was done, and brief notes taken. Efforts were made to emphasize the open-ended nature of the questions. The interviews were intended to be an honest summary of the student's personal experience in astronomy class, and not based on science content. Students were told, "There is no single 'right' answer." Interview questions were emailed to students twenty-four hours in advance. All students that participated in the interview received a $40 VISA gift card and had the option to review an audio file of their recording. See Appendix D-Interview Materials.

- *What was your experience of the class?*
- *Was this class different from other classes you have taken?*
- *How would you describe your interest in astronomy prior to this class?... How would you describe your interest in astronomy after this class?*
- *Why did you choose to take this class?*
- *Did you get what you wanted out of the class?*
- *Were there new experiences in this class?*

Figure 20 - Excerpt from the Semi-Scripted Interview

The interview data and subsequent analysis was used to gather richer, qualitative data that addressed all three of the key questions more deeply:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*
- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?*
- *Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?*

4.4 Ethical Considerations

In the United States, institutions of higher education have a committee of professional individuals that review research studies and protect the welfare of human subjects that are involved according to the federal law, "Family Educational Rights and Privacy Act" (FERPA). These committees are referred to as 'Institutional Review Boards (IRB)', 'Independent Ethics Committee (IEC); or simply 'Ethical Clearance'. This research study received review and was approved ("IRB#1108 - 2404" 2019). Participation was limited to registered students enrolled in specific introductory astronomy courses. Student grades were not affected by their participation in this study. There was no risk or harm to students. At the beginning of each semester an overview of the astronomy education research (AER) relevant to the course was discussed. For each anonymous survey, students had the option whether or not to participate. For the ADT v2.0 concept inventory quiz and course grade, students had the option to not participate. Some of the demographic questions on the ADT include the answer choice 'decline to answer'. Due to the interviewing of students, the IRB did not declare this research 'exempt', instead this research went through full review. All interviewees were presented with a release form and gave proper consent (see Appendix A-Ethical Clearance-Internal Review Board). All interview scripts and notes were securely stored on a password protected computer.

4.5 Validity and Reliability

This study contained a mixed-methods approach and therefore the validity and reliability of the quantitative research will be discussed separately from the validity and reliability of the quantitative research. Finally, a positionality statement will be detailed.

The quantitative research data collected in this study included the following instruments: Astronomy Diagnostic Test (ADT v2), and the Classroom Observation Protocol for Undergraduate STEM (COPUS). Additionally, final course grades and final letter grades were important quantitative measures. Accordingly, the collecting of this quantitative data was done with the highest level of rigor. The ADT tool has been in use in assessment of college-level introductory astronomy courses since 2002 across the U.S. Concepts are a reliable measure of introductory astronomy knowledge. Version 2 was completed after feedback from students and instructors. The official reliability and validity of the ADT assessment tool were established in 2002 after the National Science Foundation (NSF) requested and funded more rigorous examination (Deming 2002b). The COPUS instrument for measuring undergraduate STEM teaching practices was created in 2013 (Smith et al. 2013b). Real-time recording student and instructor behavior allows for a robust baseline of data to be established using the COPUS method. Validity and reliability have been established for COPUS in multiple studies across multiple STEM disciplines (Smith et al. 2014; Arum et al. 2015; Lund et al. 2015; Lund and Stains 2015; Achen and Lumpkin 2015; Connell, Donovan, and Chambers 2016). Course grades were measured using the same grading rubric in both courses. Course grading format and scales were nearly identical between courses, for example: 50% tests, 25% in-class activities/labs, and 25% at-home acitivies.

In this study the highest possible quality was the aim for conducting and reporting the qualitative research data. Criteria used to evaluate the qualitative research was from Lincoln and Guba (Lincoln and Guba 1986; Guba and Lincoln 1994). Developing trustworthiness of the qualitative research data involved: credibility, dependability, confirmability, transferability, and authenticity. Multiple methods or 'triangulation' of data collection was used in order to gain a more comprehensive view of the course experience. In particular, the interviews were semi-scripted to allow interviewees to 'tell their story'. The researcher aimed to convey that 'any answer was correct' as long as it was based on personal experience of the course. The assumption here was that students' account was based on their perceptions of reality, and may or may not reflect the larger group. The findings of this study reflect, to the best of the researcher's ability, the data collected. The goal of the interview was to understand a particular students' perspective in depth, and not necessarily a larger truth.

Threats to validity and reliability in educational research were attempted to be averted by a clearly defined research question, well-constructed study design, use of valid and reliable instruments for data collection, use of statistical analysis for appropriate comparison, and selection of representative and unbiased samples. The research positionality in relation to the research and its participants is as follows: all participants in this study were students enrolled in an ASTR 101 course between August 2018 to May 2019 at a Midwest regional comprehensive university, COPUS observers were independent consultants with no prior relation to the students or this study, the researcher has over fifteen years of teaching introductory astronomy at the college level. Positioning of the researcher in relation to this study was an attempt to deliver high quality teaching and learning, in a vibrant classroom environment that acknowledges diversity, inclusivity, and equity. Relationships with the students was considered a key element and driver of motivation. In large lecture classes establishing a good rapport is an ongoing challenge, worthy of ongoing effort. Other considerations that shaped this work are that I am a professional visual artist and a scientist, an Indigenous mixed-race scholar with a passion for communicating ideas in math and science with over three decades of experience in education as a teacher, university instructor, teacher educator, program administrator, and researcher.

Chapter Five: Results

Keeping in mind the overriding research question of this study: to what extent does culture influence student learning, particularly for underrepresented minority students in STEM, the findings of this multi-layered research will be presented in this chapter. First, an overview of student demographics will be presented; these results came solely from the ADT v2.0 concept inventory. Next, the science learning gains will be outlined starting with course grades and then separately discussing the ADT gains. Each science content gain analysis will first look at correlations involving course structure, then underrepresented minority status and sex will be added to the analysis.

The following sections will present results found related to engagement gains. Examination of COPUS behavior profiles will allow for a snapshot of what the students were doing and what the instructor was doing during classes observed. COPUS observers also directly recorded engagement each minute of the observed classes. Although no single measure is absolute, having a layered approach gives a more accurate and holistic view of the overall class experience. To support this notion, the statistical analysis of the anonymous student survey data will be presented with correlations highlighting any significant and/or surprising relationships. And finally to give a more in-depth perspective, analysis and summary of the down-the-pipeline student interviews will be presented.

5.1 Details of Class Structure: Traditional, Active, and Culturally Responsive

For the purpose of this study and subsequent analysis the following definitions are applicable:

(1) 'Traditional (T)' teaching methods as those designed to be instructor centered, lecture-based, passive for the student learner, teach by telling (S. Freeman et al. 2014). This included lectures and exams which were multiple choice and fact-based.
(2) 'Interactive Engagement (IE)' instructional methods as those where students were actively engaged in their own learning, student centered, constructivist versus expositional (Freeman et al. 2014), interactive, heads-on (always) and hands-on (usually) activities (Hake 1998).
(3) 'Culturally Responsive (CR)' methods are those that contain content and approaches based on culture as a dynamic system of beliefs most of which are unconscious, but are the philosophical pillars of our identity. Therefore a distinction is made between two slightly different notions of culture: one more specific, the other a broad-brush stroke. 'Culture' (with a capital 'C') is specifically relating to ethnicity, race or indigeneity; and 'culture' (with a lower case 'c') is in relation to individual beliefs, society's norms, or social groups for example, mainstream culture, millennial culture, Midwest culture, pop culture, etc.

There were two distinct course structures in this study. The control course included a combination of traditional (T) teaching methods and interactive engagement (IE) instructional delivery; this course is referred to as the 'IE course' in this study. The treatment course included a combination of traditional (T) teaching methods, interactive engagement (IE) instructional delivery, and increased culturally responsive (CR) curriculum and strategies; this course is referred to as the 'CR course' in this study.

5.1.2 Demographic Details of Participant Population

The participants in this study were all enrolled students in a one semester introductory astronomy college general education course intended for non-science majors (i.e. ASTR 101). This study gathered data from Fall 2018 (end of August through late December 2018) and Spring 2019 (early January through early May 2019). The number of students in the IE (control) course was approximately 60 per semester and student enrollment in the CR (treatment) course was approximately 170 each semester. The research study occurred at a post-secondary institution of higher education that is a four-year pubic comprehensive state university offering a limited number of master's degrees located in the Midwest United States. The overall demographics of the student population for the institution is as follows: 53% female, 47% male; 69% White, 18% Students of Color[3], 10% International, 3% Unknown; 87% of undergraduate students are 24 years old and younger; 44% overall graduation rate (IPEDS-NCES 2017).

The thirty-three question Astronomy Diagnostic Test (ADT) contains twenty-one science content questions along with twelve demographic questions. Both groups in this study completed the ADT. Response rates were between 68-92% in the IE (control) course and 59-91% in the CR (treatment) course. Discrepancies were due to variations in attendance.

The participants in the IE (control) course: were slightly more male (52%); perceived themselves as average or good in both math and science (74% and 70% respectively); grew up in suburban communities or small towns (40% and 32% respectively); completed math up to algebra (50%). They are studying or interest in studying: 'Humanities, Social Science, or the Arts' (29%), 'Other' (22.4%); 'Science, Engineering, or Architecture' 20.6%; 'Education' 16.8%; and 'Business' 11.2%. Students in the IE course were generally not sure or not very confident about their answers to the science content questions on this survey (69%); were not sure or expected the class to be easy (87%). Strikingly, for 85% of participants in the IE course, this was their first astronomy college class ever. The average person in the IE (control) course was less than 20 years old (76%) and White non-Hispanic (77%). Upon defining underrepresented minorities (URM) as: African-American, Hispanic-American, Native American, Africa (not American), Multicultural; and the category of non-underrepresented (non-URM) student as White non-Hispanic, Asian-American, and Asian (not American), the IE course had an 18% URM population. The average enrollment for the IE course was 59 students each semester.

[3] Defined based on IPEDS race/ethnicity definition. Students of Color include the following categories: Black or African American, Asian, Hispanic of any race, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, or Two or more races.

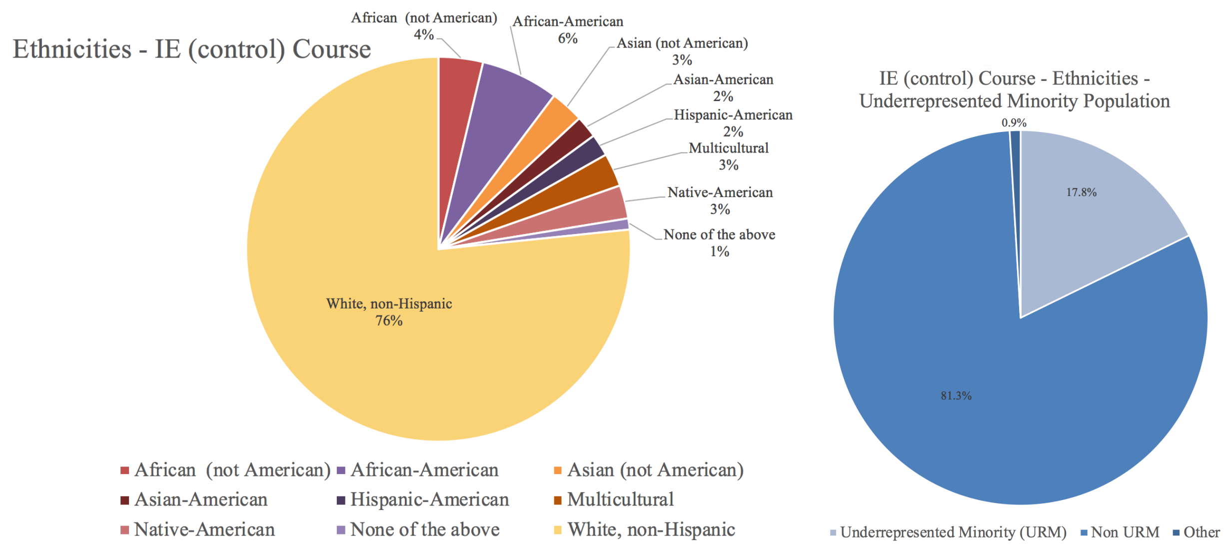


Figure 21 - IE (control) course -Ethnicities (left) and Underrepresented Minorities (URM) (right), source ADT data

Table 6 - Ethnicities and Under-represented Minorities (URM) ADT Data, IE (control) course

IE (control) course - Ethnicities	Count	Percent of Data	Confidence Interval	
African (not American)	4	3.7%	1.5% to 9.2%	3.7%
African-American	7	6.5%	3.2% to 12.9%	10.3%
Asian (not American)	3	2.8%	1.0% to 7.9%	13.1%
Asian-American	2	1.9%	0.5% to 6.6%	15.0%
Hispanic-American	2	1.9%	0.5% to 6.6%	16.8%
Multicultural	3	2.8%	1.0% to 7.9%	19.6%
Native-American	3	2.8%	1.0% to 7.9%	22.4%
None of the above	1	0.9%	0.2% to 5.1%	23.4%
White, non-Hispanic	82	76.6%	67.8% to 83.6%	100.0%
Under-represented Minority (URM)				17.8%
African (not American)	4	3.7%	1.5% to 9.2%	
African-American	7	6.5%	3.2% to 12.9%	
Hispanic-American	2	1.9%	0.5% to 6.6%	
Native-American	3	2.8%	1.0% to 7.9%	
Multicultural	3	2.8%	1.0% to 7.9%	
Non URM				81.3%
Asian (not American)	3	2.8%	1.0% to 7.9%	
Asian-American	2	1.9%	0.5% to 6.6%	
White, non-Hispanic	82	76.6%	67.8% to 83.6%	
Other				0.9%
None of the above	1	0.9%	0.2% to 5.1%	

The participants in the CR (treatment) course: were slightly more male (54%); perceived themselves as average or good in both math and science (76% and 79% respectively); nearly two-thirds grew up in small towns or suburban communities (31.3% and 30.9% respectively); completed math up to algebra (43%). Students in the CR course indicated their major or interest if undecided as: Science, Engineering, Architecture (31.6%); Other (22.4%); Business 20%; Humanities, Social Sciences or the Arts (16.1%), and Education (9.9%). In general the CR course participant were not sure or not very confident about their answers to the science content questions on this survey (74%) and are not sure about the level of difficulty expected (64%). Amazingly, for 93% of students in CR (treatment) course, it was their first astronomy college class ever. The average person in the CR course was less than 20 years old (72%) and White non-Hispanic (61%). Upon defining under-represented minorities (URM) as: African-American, Hispanic-American, Native American, African (not American), Multicultural; and the category of non-underrepresented (non-URM) student as White non-Hispanic, Asian-American, and Asian (not American), the CR course had a 19% URM population. The average enrollment for the CR course was 170 students each semester.

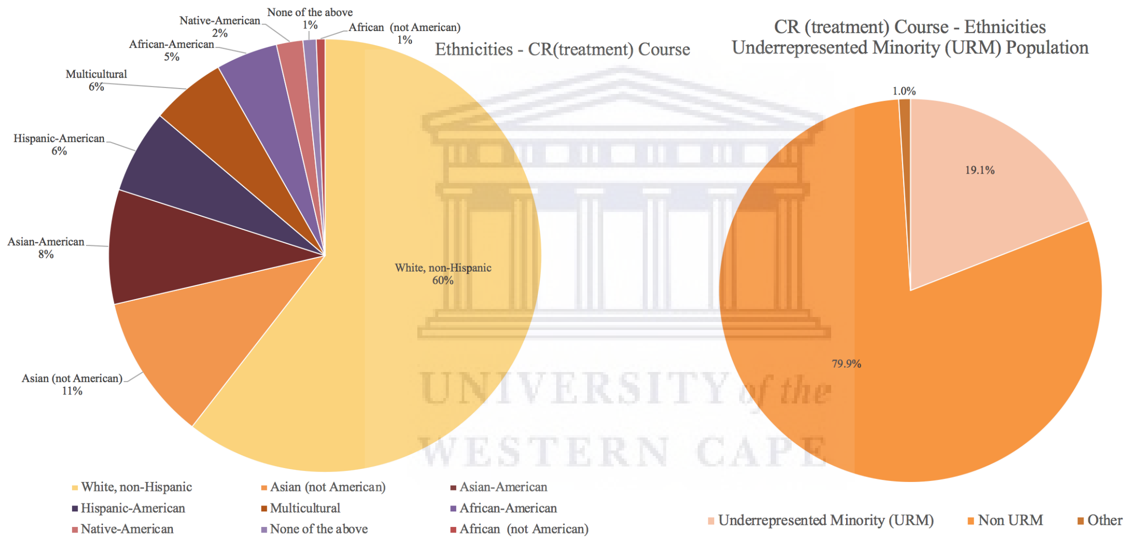


Figure 22 - CR (treatment) course - Ethnicities (left) and Underrepresented Minorities (URM) (right), source ADT data

In summary, both groups in this study included approximately 80% majority (non-URM) students and 20% minority (URM) students.

Table 7 - Ethnicities and Underrepresented Minorities (URM) ADT Data, CR (treatment) course

CR (treatment) course - Ethnicities	Count	Percent of Data	Confidence Interval	
White, non-Hispanic	184	60.5%	54.9% to 65.9%	60.5%
Asian (not American)	33	10.9%	7.8% to 14.9%	71.4%
Asian-American	26	8.6%	5.9% to 12.2%	79.9%
Hispanic-American	19	6.3%	4.0% to 9.6%	86.2%
Multicultural	17	5.6%	3.5% to 8.8%	91.8%
African-American	14	4.6%	2.8% to 7.6%	96.4%
Native-American	6	2.0%	0.9% to 4.2%	98.4%
None of the above	3	1.0%	0.3% to 2.9%	99.3%

African (not American)	2	0.7%	0.2% to 2.4%	100.0%
Under-represented Minority (URM)				19.1%
African (not American)	2	0.7%	0.2% to 2.4%	
African-American	14	4.6%	2.8% to 7.6%	
Hispanic-American	19	6.3%	4.0% to 9.6%	
Native-American	6	2.0%	0.9% to 4.2%	
Multicultural	17	5.6%	3.5% to 8.8%	
Non URM				79.9%
Asian (not American)	33	10.9%	7.8% to 14.9%	
Asian-American	26	8.6%	5.9% to 12.2%	
White, non-Hispanic	184	60.5%	54.9% to 65.9%	
Other				
None of the above	3	1.0%	0.3% to 2.9%	1.0%

Note – In accordance with the Internal Review Board (IRB or Ethical Clearance), students were given the opportunity to opt-out of the ADT data collection, which also included course grade. A total of 32 students declined participation, this included 9 students in the IE (control) course and 23 students in the CR (treatment) course. Survey participation was repeatedly optional and informed consent was the first step of every survey.

5.2 Results Showing Science Content Learning Gains

The following results show learning gains in science content, which in the context of this study means knowledge acquisition based on concepts contained in an introductory college level general astronomy course. Instruments used to measure science learning gains were: final course grades and Astronomy Diagnostic Test (ADT) concept inventory normalized gains.

5.2.1 Course Grades

To measure science content learning gains course final grades were analyzed to address the following two key questions:

- *How does culturally inclusive curriculum quantitatively affect knowledge acquisition for ASTR 101 students?* (Note: Course grades are able to measure quantitative effects of knowledge acquisition, and not qualitative effects.)
- *Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?*

Recall that both groups in this study, the IE course and the CR course, had the same grading rubric, the same grading structure, and the same instructor. The primary and relevant difference between the two groups was course structure. The IE (control) course was designed as a traditional (T) course (i.e. lectures) that also included interactive engagement (IE) (i.e. labs and activities). The CR (treatment) course design included: traditional (T), interactive engagement (IE), and increased culturally responsive pedagogy (CRP).

5.2.1.1 Knowledge Acquisition Gains & Course Grades

This part of the analysis investigated correlations between final course grades and three variables: course design, underrepresented minority (URM) status, and sex. Numerical final course grades were binned into the standard letter categories as follows: ‘A’ is 100 to 90, ‘B’ is 89 to 80, ‘C’ is 79 to 70, ‘D’ is 69 to 60, ‘F’ is 59 or lower, and ‘W’ is a withdraw from the class. Note that in South Africa and other places the term ‘race’ is equivalent to the term used in the United States, which is ‘ethnicity’. The term underrepresented minority (URM) is defined in this study as: African-American, Hispanic-American, Native American, African (not American), and Multicultural. Likewise, the category of non-underrepresented (non-URM) student is defined as White non-Hispanic, Asian-American, and Asian (not American).

Overall results of course grades are as follows. There were 315 final grades from the CR (treatment) course and 118 final grades from the IE course, for a total of 433 final grades analyzed. Including both groups the average final grade was 83.4%. The average grade in the CR course was 84.0% as compared to the average grade in the IE course of 81.6%. This is a 2.4-point difference or a 3% increase. **>>> Significant Result 1a.** Students in the course with increased culturally responsive (CR) pedagogy, or the treatment course, *learned more science* content as indicated by *slightly higher* values for *final course grades*. This result was confirmed by a ranked T-Test and is *clearly significant* with a p-value of 0.012, effect size 0.269, sample size 417, and a 95% confidence level .

Table 8 - Final Course Grades details for two distinctly different course formats.

CR (treatment) course tends to have slightly higher values for final grade than IE (control) course.		
Ranked T-Test	Basic	Advanced
Statistical Significance (p-value)	Clearly significant	0.01208135
Effect Size (Cohen's d)	Small	0.269
Difference Between Averages (IE – CR)		-2.36
Confidence Interval of Difference		-6.01 to 1.29

	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
CR (treatment) Course	305	89.4	84.0	25,616.0	82.1 to 85.9	17.0
IE (control) Course	112	85.1	81.6	9,142.4	78.5 to 84.7	16.7

Considering letter grades with both groups combined shows that overall there were many good grades. Specifically, this breakdown of grades was: 44.2% ‘A’s, 27.2% ‘B’s, 10.4% ‘C’s, 6.4% ‘D’s, 7.9% ‘F’s and 4 ‘W’s or withdraws.

Breaking these letter grades down by course structure the following results were found. In the IE (control) course most students earned a ‘B’ (36.4%), followed closely by students receiving an

'A' (32.7%), only 10% of the students received a 'C', 'D' grades were assigned to 7.3% of students in the control course, 'F's were 8.2%, and W's were the final 5.5%.

In comparison, *nearly half* of the students in the CR (treatment) course earned an 'A' (48.5%), followed by the 23.7% the received a 'B'. Similar to the IE (control) course, 10.5% of the CR course students received a 'C'. Fewer students in the CR (treatment) course earned the lowest grades ('D's, 'F's and 'W's) as compared to students in the IE (control) course (6.1%, 7.8%, 3.4%-CR course versus 7.3%, 8.2%, 5.5%-IE course).

Although *no statistically significant relationship* between letter grade and course was found due to the p-value of 0.068, (recall that the p-value must be < 0.05 for statistical significance), there was statistical significance determined between individual cells. Adjusted residuals were used to assess whether or not an individual cell is statistically significantly above or below expectations. Essentially the adjusted residual asks, "Does this cell have more values in it than expected if there was no relationship between these two variables?" In this case, students who earned an 'A' in the treatment course was *much higher than typical*, relative to students who earned an 'A' in the control course. The p-value calculated from the adjusted residuals show the degree of significance of this result is a p-value less than 0.01 at the 95% confidence level.
>>> Significant Result 1b. Students in the course with increased culturally responsive (CR) pedagogy, or the treatment course, *learned more science* content as indicated by *much higher than typical* values of letter 'A' grades earned. This result was confirmed by a z-test on the adjusted residuals of individual cells and is *clearly significant* with a p-value < 0.01 at a 95% confidence level .

Table 9 - Statistical analysis of Letter Grades and Course Structure:

There is not quite a statistically significant relationship between letter grade and course structure.

Chi-Squared Test	Basic	Advanced
Statistical Significance (p-value)	Not quite significant	0.06779304
Effect Size (Cramér's V)	Small	0.15928525
Sample Size		405

Table 10 - Adjusted Residuals of Course Structure and Letter Grades. A single arrow indicates p < 0.05. A double arrow indicates p < 0.01.

	CR (treatment) Course	IE (control) Course
A	∧∧ 48.5%	∨∨ 32.7%
B	∨ 23.7%	∧ 36.4%
C	10.5%	10.0%
D	6.1%	7.3%
F	7.8%	8.2%
W	3.4%	5.5%

5.2.1.2 Underrepresented Students & Course Grades

The key question to address here was:

Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?

The analysis began with correlations between grades and letter grades paired with ethnicity and underrepresented minority (URM) status. There is a *subtle but statistically significant* relationship between ethnic background and numerical grade in the overall study (p-value 0.0340, effect size-Cohen's f of 0.236). Given the class average overall for both groups in the study is 83.4%, it can be seen that the following ethnic groups have achieved higher than average overall course grades: Asian-not American (88.6%), White-not Hispanic (85.5%), Hispanic-American (85%), Multicultural (84.3%). Likewise, the following groups received lower than the average course grades: African-not American (80.6%), Asian-American (78.6%), Native American (75.4%), and African-American (74%). Overall, (including both the CR course and the IE course), the average grade for URM is 80.3% and 85.3% for non-URM in this study.

It was useful to look at URM students in the CR (treatment) course as compared to URM students in the IE (control) course. To accomplish this examination a multivariable contingency table was analyzed across grades, course structure, and URM status. Here it can be seen that the average URM student in the CR course earned an 81.5% course grade, as compared to the URM student in the IE course who earned on average a grade of 76.9%. This is a 4.6-point variance or equivalently a *6% increase* in final course grade for the CR course. **>>> Significant Result 2a**. *Underrepresented minority (URM) students* were positively affected by participating in the course with increased cultural relevancy (CR), also designated the treatment course. This result was measured by the URM students in the CR course earning an average grade that was *nearly 5 points* higher than URM students in the IE course. A p-value of 0.00014 confirms there is a *statistically significant relationship* between these variables.

Table 11 - Details of Course Grades correlated across Course Structure and URM status

		IE (control) Course		CR (treatment) Course	
	Total	URM	non-URM	URM	non-URM
Sample size	376	18	82	52	224
Average	84.4	76.9	83.3	81.5	86
Median	88.7	79.4	87.5	88.8	89.9
Standard Deviation	15.9	11.4	17.1	20.2	14.3
Standard Error	0.8	2.7	1.9	2.8	1.0
Overall Stat Test of Averages	0.00014	p-value			

Similarly, upon investigating the correlations between: letter grades, course structure, and URM status it can be seen that *nearly half* (47.2%) of the URM students in the CR course received an 'A' grade as compared to URM students in the IE course, where only 6.3% received an 'A' grade. This is a well-defined difference in 40.9 points or equivalently a 649% increase in the number of URM students receiving an 'A' grade between the CR course and the IE course. **>>> Significant Result 2b.** Underrepresent minority (URM) students in the course with increased cultural responsiveness, the CR course, were *much more likely* to earn an 'A' grade in the course as compared to URM students in the IE course as indicated by a three-variable contingency table with p-value 0.00001. In fact, URM students in the CR course were more likely to earn an 'A' grade than non-URM students in the IE course (47.2% versus 41.5%).

Table 12 - Three-variable contingency table results: Letter Grade, Course Structure, URM status

		IE (control) Course		CR (treatment) Course	
	Total	URM	non-URM	URM	non-URM
Sample size	364	16	82	53	213
A	47.3%	6.3%	41.5%	47.2%	52.6%
B	26.4%	37.5%	34.1%	18.9%	24.4%
C	9.3%	12.5%	6.1%	7.5%	10.8%
D	6.3%	31.3%	3.7%	11.3%	4.2%
F	6.6%	6.3%	8.5%	9.4%	5.2%
W	4.1%	6.3%	6.1%	5.7%	2.8%
Overall Stat Test of Averages	0.00001	p-value			

Continued analysis to gain deeper insights led to a four-variable correlation table between: grades, course structure, URM status, and sex. Here, it can be seen that female URM students in the treatment course had the highest grade average of all URM students in the study (83.6%). **>>> Significant Result 3a.** *Female underrepresented minority students (URM) were most positively affected* by participating in the course with increased cultural relevancy (CR course). This result was measured by calculating the female URM students average course grade of 83.6%. This is higher than the male URM students in the CR (treatment) course (80.4%); and *significantly higher* than both the female URM students and the male URM students in the IE course (74.6% and 78.8% respectively). Comparison between female URM student grades in the IE course as compared to female URM student grades in the CR course, yields a *12% increase* in course grade for the CR course students. This result for female URM students in the CR course is also higher than for the grades earned by female non-URM students in the IE course (82.5%). A p-value of 0.00008 confirms there is a *statistically significant relationship between these variables*.

Table 13 - Four variable contingency table between: Grades, Course Structure, URM status, and Sex

		IE (control) Course				CR (treatment) Course			
	Total	URM		non-URM		URM		non-URM	
		Female	Male	Female	Male	Female	Male	Female	Male
Sample size*	374	8	10	40	42	20	30	101	118
Average	84.4	74.6	78.8	82.5	83.9	83.6	80.4	86	86.1
Median	88.7	79.1	80.1	89.2	85.5	90.8	86.4	91.7	89.4
Standard Deviation	15.9	9.8	12.8	19.8	14.4	21.1	20.1	15.4	13.6

Standard Error	0.8	3.5	4	3.1	2.2	4.7	3.7	1.5	1.3
Overall Stat Test of Averages		0.00008		p-value			* 5 students declined to answer		

In a similar way, analysis of the four variable relationship was measured in a contingency table consisting of: letter grade, course structure, URM status, and sex. Analogous results were found. To be clear, the questions examined here were: What percent of the grades earned by URM women in the CR course were 'A's? How does this compare with their counterparts in the IE course? The results show that *over half* the URM women in the CR course earned an 'A' (52.4%). This is a 52.4-point increase over the female URM students in the IE course of which there were no 'A's earned by this subgroup. **>>> Significant Result 3b.** *Female underrepresented minority students (URM) were most positively affected* by participating in the course with increased culturally responsive (CR) pedagogy, or the treatment course. This result was measured by calculating that female URM students in the CR course most often earned an 'A' in the course (52.4%). This is significant because URM females in the IE course did not earn any 'A's. This result is also *significantly higher* than the male URM students in the IE course who earned 'A's only at 11%; and *higher* than the male URM students in the CR course that earned 44.8% 'A' letter grades; and non-URM females and non-URM males in the IE course (51.4% and 31.8% respectively). In fact, the URM women in the CR course earned a slightly higher percentage of 'A' letter grades even compared to non-URM males in the CR course (50%). A p-value of 0.00109 confirms there is a *statistically significant relationship between these variables*. The only subgroup grades higher than URM female student grades in the CR course was non-URM female student grades in the CR course.

>>> Significant Result 4. Additionally, male URM students in the CR course received higher grades and earned mostly 'A's. The male URM students *significantly* out scored both their male counterpart in the IE course regardless of their URM status (URM male students that earned 'A's in the IE course at 11.1%, non-URM male students that earned 'A's in the IE course was 31.8%).

Table 14 - Four variable correlation: Letter Grade, Course Structure, URM status, and Sex

		IE (control) Course				CR (treatment) Course			
	Total	URM		Non-URM		URM		Non-URM	
		Female	Male	Female	Male	Female	Male	Female	Male
Sample size	362*	7	9	40	42	21	29	97	112
A	47.2%	0.0%	11.1%	51.4%	31.8%	52.4%	44.8%	55.7%	50.0%
B	26.5%	28.6%	44.4%	27.0%	40.9%	19.0%	20.7%	21.6%	26.8%
C	9.4%	14.3%	11.1%	2.7%	9.1%	4.8%	10.3%	10.3%	10.7%
D	6.4%	49.2%	22.2%	5.4%	2.3%	9.5%	10.3%	3.1%	5.4%
F	6.6%	0.0%	11.1%	13.5%	4.5%	9.5%	10.3%	7.2%	3.6%
W	3.9%	14.3%	0.0%	0.0%	11.4%	4.8%	3.4%	2.1%	3.6%
Overall Stat Test of Averages		0.00109				* 5 students declined to answer			

In summary, to address the key questions:

- *How does culturally inclusive curriculum quantitatively affect knowledge acquisition for ASTR 101 students?* The course with increased culturally responsive (CR) pedagogy, the treatment course, *achieved greater gains in science content learning*, as indicated by a higher class average grade and a higher percentage of students earning an 'A' in the course. Remarkably, 4 out of every 6 students in the CR course earned an 'A' or a 'B' as a final grade (66.1%), as compared to the IE course where 2.6 out of every 6 students earned an 'A' or a 'B' (28.6%). See Table 12. In addition, female non-URM students in the CR course earned the highest percentage of 'A's compared to any other subgroup in this study, including male non-URM students in the CR course (55.7% earned an 'A', versus 50% respectively). See Significant Results 1a, 1b and Table above.

- *Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy*? Yes. Underrepresented students in the course with increased culturally responsive (CR) pedagogy, the treatment course, showed positive learning gains as measured by average grades and letter grades as compared to the IE course. See Significant Results 2a and 2b. More specifically, underrepresented (URM) female students in the increased cultural relevancy (CR), or treatment course, showed the largest gains especially when compared to their counterparts, other underrepresented females in the IE course. Strikingly, more than 7 out of every 10 URM students in the CR course earned an 'A' or a 'B' as a final grade (71.4%), as compared to less than 3 out of every 10 URM students in the IE course (28.6%). See Table 14.

Furthermore, both males and female URM students in the CR course earned a higher percentage of 'A's than URM students in the IE course. Female URM students were affected in the largest capacity, but male URM students in the CR course also were positively affected as shown by out-scoring all other males in the IE course. See Significant Result 3c.

Table 15 - Summary of Assessment Outcomes of two key questions: Learning Gains and URM students

Instrument	Science Learning Gains?	URM students affected positively?
Course Grades -Numerical	✓ Result 1a	✓ Result 2a, Result 3a
Course Grades - Letter	✓ Result 1b	✓ Result 2b, Result 3b, Result 4

5.2.2 Astronomy Diagnostic Test (ADT)

Concept inventories with national databases are the industry standard for measuring science content gain, for introductory astronomy at the college level, the most widely used concept inventory is a 33 question pre and post quiz called the Astronomy Diagnostic Test (ADT). To measure *science content learning gains* results of the ADT concept inventory, were analyzed to address the following two key questions:

- *How does culturally inclusive curriculum quantitatively affect knowledge acquisition for ASTR 101 students?*
- *Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?*

The overall results were measured for the IE course and the CR course using normalized gain, <g>. Recall: The pre-course and the post-course results were used to calculate the average normalized gain <g>.

$$< g > \equiv \frac{\% < S_f > \; - \% < S_i >}{100 - \% < S_i >}$$

Where $< S_f >$ and $< S_i >$ are final (post) and initial (pre) class averages (Hake 1998).

5.2.2.1 Knowledge Acquisition Gains & the ADT

Results of the ADT concept inventory for this study were as follows: the class average normalized gain for the IE course was 22% and class average normalized gain for the CR course was 28%. This variance is a 6.1-point difference or nearly a 30% increase in the class average normalized gain of the ADT results for the CR course (28.2%).

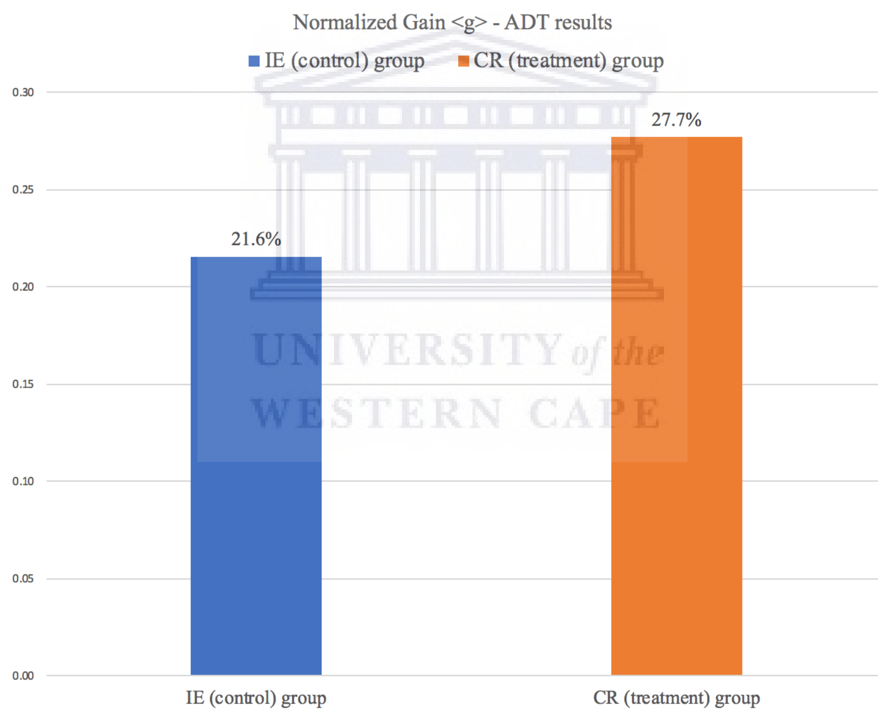


Figure 23 - Results of the ADT class Average Gain, IE (control) course (on left), CR (treatment) course (on right)

Table 16 - ADT Overall results: Class Averages of Normalized Gain based on pre-test scores and post-test scores

ADT results	Pre score	Pre %	Post score	Post %	<Sf> - <Si>	100 - <Si>	Class Avg <g>
IE (control) course	6.796	32.360	9.848	46.893	14.533	67.640	0.216
CR (treatment) course	6.650	31.665	10.624	50.591	18.926	68.335	0.277

An alternate way to consider normalized gain is to first calculate the individual gain, then take the average across all individual gains, $<g>_{indiv}$. Here a similar result is found. The CR course has a higher average individual gain (29.0%) than the IE course (22.3%). This variance is a 6.7-point difference or over a 30% increase.

>>> Significant Result 5. Overall, the course with increased culturally responsive (CR) pedagogy, the treatment course, *achieved greater gains in science content learning*, as indicated by a higher average individual gain on the ADT concept inventory. These results were confirmed by a T-test that found the results are *clearly significant* with a p-value of 0.03, effect size-Cohen's d of 0.306, sample size 278 at a confidence level of 95%.

Table 17 - Details of T-test statistical correlation between ADT Average Individual Gain and Course Structure

CR (treatment) course tends to have slightly higher values for ADT normalized gain than IE (control) course.						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	0.027649				
Effect Size (Cohen's d)	Small	0.306				
Difference Between Averages (IE – CR)		-0.0692				
Confidence Interval of Difference		-0.131 to -0.00773				
	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
CR (treatment) course	200	0.3	0.3	58.4	0.261 to 0.323	0.2
IE (control) course	78	0.3	0.2	17.4	0.170 to 0.276	0.2

5.2.2.2 Underrepresented Students & the ADT

In addition to positive science content-based learning gains in the course with the increased culturally responsive (CR) pedagogy, or treatment course, one key aspect of this study was to measure learning gains for underrepresented students. Here underrepresented students are defined as 'underrepresented minority groups' (URM) which in the U.S. includes: African-American, Hispanic-American, Native American, Multicultural, and African (not American). The ethnic categories of: White non-Hispanic, Asian-American, and Asian (not American) are considered majority groups in this study.

Results from the ADT confirm that the underrepresented minority (URM) students in the CR course earned an average individual gain of 29.4% which *is higher than any other group in this study*, including non-URM students in the CR course, non-URM students in the IE course, and URM students in the IE course. This result is higher than the class average gain of 24.65% and the average individual gain 27.2%. **>>> Significant result 6.** Underrepresented minority (URM) students in the course with increased cultural responsiveness (CR), or the treatment course, achieved the *overall highest positive learning gains* as compared to any other group in this study as measured by the ADT concept inventory. As compared to their URM student counterparts in the IE (control) course who earned an average gain of 10.6 gain, there was almost a 20-point difference or equivalently a 177% increase in the CR course. A Chi-squared test on the three-variable correlation table confirmed this result is a *statistically significant* relationship between these variables with a p-value of 0.01109.

Table 18 - URM students in the CR (treatment) course show the highest learning gain across all groups in the study as seen in this three-variable contingency table: Course Structure x URM status x ADT gain

	Avg. Individual gain <g>	Sample size	Median	Confidence Interval of Average	Standard Deviation
URM – CR (treatment) Course	29.376	35	0.31250	0.227 to 0.361	0.19435

non URM – CR Course	28.628	165	0.27780	0.251 to 0.321	0.22906
CR course only	29.002	200	0.29515		0.21171
non URM - IE (control) Course	25.74	61	0.28570	0.199 to 0.316	0.22740
URM - IE Course	10.589	16	0.14380	-0.0222 to 0.234	0.24035
IE Course only	22.3	78	0.25000	0.170 to 0.276	0.237
CR and IE Courses combined	27.2	281	0.278	0.2448 to 0.2985	0.228

Statistical analysis of a four-variable contingency table revealed even more detailed results. A Chi-squared test confirms a *statistically significant* relationship between ADT learning gains and the following variables: course structure, URM status, and sex. **>>> Significant result 7.** URM male students in the CR (treatment) course had *higher ADT learning gains* than URM males and URM females in the IE (control) course as indicated by a *statistically significant* analysis using a four-variable correlation table. This result was determined to be a *statistically significant* relationship between these variables with a p-value of 0.04106.

In addition, URM males in the CR (treatment) course did equally as well in learning gains as all other groups in both the CR course and IE course, including non-URM females and non-URM males.

Table 19 - Statistically significant results between variables of: ADT gain, Course Structure, URM status, and Sex

		IE (control) Course				CR (treatment) Course			
		URM		non-URM		URM		non-URM	
	Total	Female	Male	Female	Male	Female	Male	Female	Male
Total Count	271	7	9	28	32	13	21	75	86
Average ADT <g>	0.3	0.2	0.1	0.3	0.2	0.2	0.3	0.3	0.3
Overall Stat of Test of Averages	0.04106								

There is a *statistically significant* relationship between URM status and learning gain in the IE course. A URM student in the IE course had an average gain of 10.6% on the ADT, where the non-URM student secured a 25.7% gain on the ADT on average. This is a variance of 15 percentage points or 142% difference. **>>> Significant Result 8.** An underrepresented minority (URM) student in the IE course, or control course, was more likely to have a *noticeably lower* ADT learning gain than a non-URM student, or majority student, in the same course. This result is *statistically significant* as indicated by statistical correlation using an ANOVA test where the p-value is 0.03, effect size-Cohen's f of 0.293, and sample size 77.

Table 20 - IE course, ADT results, URM status is correlated to ADT learning gains

ANOVA	
P-Value	0.0332
Effect Size (Cohen's f)	0.293

URM status	Average	Median	Sample Size	Confidence Interval of Average	Standard Deviation
non-URM	0.2574	0.2857	61	0.199 to 0.316	0.23
URM	0.1059	0.1438	16	-0.0222 to 0.234	0.24
Total	0.2	0.3	77		

Other demographic correlations with ADT learning gains.

The following results were found across all participants in this study (both IE-control and CR-treatment courses). Although some of the findings are expected, they are included here for completeness.

There is a statistically significant relationship between ethnic background and ADT learning gains as indicated by an ANOVA test p-value 0.0117, effect size-Cohen's f of 0.283, and sample size of 277. Above average (27.2%) learning gains by ethnic group are: Asian (not American), Hispanic-American, White non-Hispanic, Multicultural, and Native-American. This includes three out of the five URM groups. Below average learning gains were: African (not American), Asian-American, and African-American. This includes two out of the five URM groups.

Table 21 - Statistically significant correlation between Ethnic Background and ADT Learning gains

ANOVA						
P-Value	0.0117					
Effect Size (Cohen's f)	0.283					
Summary						
Group	Average	Median	Sum	Sample Size	Confidence Interval of Average	Standard Deviation
Asian (not American)	0.4	0.4	8.5	22	0.317 to 0.460	0.2
Hispanic-American	0.3	0.3	4.2	14	0.208 to 0.396	0.2
White, non-Hispanic	0.3	0.3	51.6	183	0.248 to 0.316	0.2
Multicultural	0.3	0.3	4.1	15	0.186 to 0.363	0.2
Native-American	0.3	0.3	0.8	3	-0.249 to 0.794	0.2
African (not American)	0.2	0.2	1.0	4	0.00900 to 0.471	0.1
Asian-American	0.1	0.1	2.8	21	0.0584 to 0.209	0.2
African-American	0.1	0.1	1.9	15	-0.0522 to 0.299	0.3

There is a statistically significant relationship between self-reported merit in science and ADT learning gains (p-value 0.0048, effect size-Cohen's f of 0.266). Students that claimed they were good at science scored highest on the ADT learning gains.

Table 22 - Statistically significant correlation between self-reported competency in science and ADT learning gains

ANOVA	
P-Value	0.0048
Effect Size (Cohen's f)	0.266
Summary	

Group	Average	Median	Sum	Sample Size	Confidence Interval of Average	Standard Deviation
Very good	0.4	0.4	8.5	22	0.281 to 0.491	0.2
Good	0.3	0.4	25.4	76	0.286 to 0.382	0.2
Very poor	0.3	0.3	1.9	7	0.189 to 0.359	0.1
Poor	0.3	0.3	9.7	37	0.196 to 0.329	0.2
Average	0.2	0.2	30.1	137	0.180 to 0.259	0.2

There is a subtle but statistically significant relationship between self-reported merit in math and ADT learning gains (p-value 0.0124, effect size-Cohen's f of 0.239). Student that reported being very good in math had the highest ADT learning gains (38.6%).

Table 23 - Subtle but statistically significant correlation between self-reported competency in math and ADT learning gains

ANOVA	
P-Value	0.0124
Effect Size (Cohen's f)	0.239

Summary						
Group	Average	Median	Sum	Sample Size	Confidence Interval of Average	Standard Deviation
Very good	0.4	0.4	10.0	26	0.288 to 0.484	0.2
Good	0.3	0.3	28.4	94	0.257 to 0.348	0.2
Poor	0.3	0.3	8.4	29	0.206 to 0.372	0.2
Very poor	0.3	0.3	3.1	12	0.188 to 0.325	0.1
Average	0.2	0.2	25.7	118	0.176 to 0.260	0.2

There is a subtle but statistically significant relationship between last math class taken and ADT learning gains (p-value 0.0203, effect size-Cohen's f of 0.215). Student that completed math courses up to and including Calculus had the highest ADT learning gains (36.5%).

Table 24 - Subtle but statistically significant correlation between highest level math class taken and ADT learning gains

ANOVA	
P-Value	0.0203
Effect Size (Cohen's f)	0.215

Summary						
Group	Average	Median	Sum	Sample Size	Confidence Interval of Average	Standard Deviation
Calculus	0.4	0.3	17.9	49	0.304 to 0.426	0.2
Pre-Calculus	0.3	0.3	21.2	76	0.228 to 0.331	0.2
Geometry	0.3	0.3	2.5	10	0.0913 to 0.419	0.2
Trigonometry	0.3	0.3	4.8	19	0.159 to 0.348	0.2
Algebra	0.2	0.2	29.2	126	0.191 to 0.273	0.2

There is a subtle but statistically significant relationship between home community and ADT learning gains (p-value 0.000826, effect size-Cohen's f 0.203). Student that went to high school not in the U.S.A. had the highest ADT learning gains (38.1%).

Table 25 - Subtle but statistically significant correlation between home community and ADT learning gains

ANOVA	
P-Value	0.000826
Effect Size (Cohen's f)	0.203

Summary						
Group	Average	Median	Sum	Sample Size	Confidence Interval of Average	Standard Deviation
Not in the USA	0.4	0.4	12.2	32	0.329 to 0.434	0.1
Rural	0.3	0.3	10.1	34	0.222 to 0.371	0.2
Suburban	0.3	0.3	24.4	92	0.213 to 0.319	0.3
Small town	0.3	0.3	22.4	88	0.206 to 0.302	0.2
Urban	0.2	0.2	7.3	35	0.135 to 0.280	0.2

There are no statistically significant correlations measured between ADT learning gains and the following indicators in this study: age, sex, college major, confidence level in answers, level of difficulty expected/experienced, or the number of previous astronomy courses completed across all participants in this study.

In summary, to address the key questions:

- *How does culturally inclusive curriculum quantitatively affect knowledge acquisition for ASTR 101 students?* The course with increased culturally responsive (CR) pedagogy, the treatment course, achieved greater gains in science content learning, as indicated by a higher class average normalized gain and a higher average individual gain on the ADT concept inventory. See Significant Result 5.

- *Will underrepresented students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy*? Yes. Underrepresented students in the course with increased culturally responsive (CR) pedagogy, the treatment course, showed positive learning gains as measured by the ADT concept inventory as compared to the IE (control) course. See Significant Result 6. More specifically, underrepresented (URM) male students in the increased culturally responsive (CR) pedagogy, or the treatment course, showed the largest gains especially when compared to their counterparts, other underrepresented males in the IE (control) course. See Significant Results 7 and 8.

To summarize, the assessment outcomes of the two key questions as seen above using the instruments of course grades and ADT learning gains found multiple measures of positive results.

Table 26 - Summary of Assessment Outcomes of two key questions: Learning Gains and URM students

Instrument	Science Learning Gains?	URM students affected positively?
Course Grades -Numerical	✓ Result 1a	✓ Result 2a, Result 3a
Course Grades - Letter	✓ Result 1b	✓ Result 2b, Result 3b, Result 4
ADT - overall class normalized gains	✓ Result 5	✓ Result 6
ADT - average individual normalized gains	✓ Result 5	✓ Result 6, Result 7, Result 8

Table 27 - Summary of Significant Results - Course Grades and ADT gains

Assessment Instrument - Course Grades	Ref. page.	Science Content Gain	URM student gain due to increased CR
Significant Result 1a *Students in the CR course had slightly higher course grades than students in the IE (control) course.*	p. 81	x	
Significant Result 1b *Students in the CR course earned more A's than students in the IE (control) course.*	p. 82	x	
Significant Result 2a *URM students in CR course had higher grades than URM students in the IE (control)*	p. 83	x	x
Significant Result 2b *URM students in CR course more likely to earn an 'A' than IE (control) URM students & IE (control) non-URM*	p. 83	x	x
Significant Result 3a *Female URM students in the CR course more likely to earn a higher grade than URM males in CR course and all URM students in IE (control) course.*	p. 84	x	x
Significant Result 3b *Female URM students in the CR course earned more 'A's as compared all other subgroups (URM and non-URM) in the study except for female non-URM students in the CR course.*	p. 85	x	x
Significant Result 4 *Male URM students in the CR course received higher grades than male and female URM students in the IE (control) course; and received more ‘A’s as compared to both URM and non-URM males in the IE (control) course.*	p. 85	x	x
Assessment Instrument - ADT gains			
Significant Result 5 *Students in the CR course had higher ADT individual gains than students in the IE (control) course.*	p. 88	x	
Significant Result 6 *URM students in CR course achieved the overall highest positive learning gains as compared to any other group in this study as measured by the ADT concept inventory.*	p. 88	x	
Significant Result 7 *URM male students in CR course had higher ADT learning gains than URM males and URM females in the IE (control) course*	p. 89	x	x
Significant Result 8	p. 89	x	x

An URM student in the IE (control) course, was more likely to have a noticeably lower ADT learning gain than a non-URM student in the same course.

5.3 Results Showing Engagement Gains

To describe and measure engagement gains the following instruments were applied: direct observation of faculty and students during class time using COPUS, student survey data, and student interviews.

Specific questions that were examined by these instruments were:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?;*
- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?*
- *Will underrepresented minority students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?*

Recall that the COPUS observational tool and the anonymous student surveys will address the first two questions only. Student interview data will speak to all three key questions.

Table 28 - Engagement gains as indicated by three key questions, as measure by three different instruments

	COPUS	Surveys	Interviews
Will students find ASTR 101 more engaging if the content is more culturally relevant	✓	✓	✓
How does culturally inclusive curriculum qualitatively and quantitatively affect knowledge acquisition for ASTR 101 students	✓	✓	✓
Will underrepresented minority students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy			✓

5.3.1 Observational Protocol COPUS

Knowledge that the observers were consistent in their recording of classroom behavior was important to this study. To compare inter-rater reliability (IRR) the Cohen's kappa scores were calculated for observers pairs (Landis and Koch 1977; Smith et al. 2013b). To calculate the kappa scores the following formula was used:

$$\kappa = \frac{p_o - p_e}{1 - p_e}$$

where κ is the kappa score and measures the agreement of the two raters
p_o is the relative observed agreement between rates
p_e is the hypothetical probability of chance agreement.

Table 29 - Average Interrater Reliability (IRR) kappa scores; values between 0.61-0.80 show 'substantial agreement' (Landis and Koch 1977)

	All codes (±SE)
IE (control) class 1	0.697 (0.04)
CR (treatment) class 1	0.715 (0.04)
IE (control) class 2	0.687 (0.03)
CR (treatment) class 2	0.727 (0.04)
Average	0.711 (0.03)

The average kappa scores ranged from 0.687 to 0.727 with an overall average of 0.704 (Table 2). According to statistical theory this indicates *substantial agreement* for interrater reliability (IRR) after taking into account both the observers actual values and the possibility of chance agreement (Landis and Koch 1977).

Using the classroom observation instrument, COPUS, the analysis of this data set addresses the following questions:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*
- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?*

Recall COPUS is a recording of student and instructor behavior at each minute interval during the class time. The hypothesis here is that this method of detailed book-keeping of classroom behavior will show: increased engagement in the culturally responsive (CR) course, and quantify the engagement gain between the IE course and the CR course.

Specifically, this analysis was done in following steps: (I) COPUS profiles were created for each course format, for both students and instructors, and (II) Analysis of COPUS observers' recording of 'level of engagement' (low, medium, or high), for both the IE course (control) and the CR course (treatment); (III) measurement of engagement using correlation analysis as a function of the key variable 'level of engagement'. All statistical tests were done at the 95% confidence level.

5.3.1.1 COPUS Profiles

COPUS profiles were created for each the of the two distinct course formats: the IE course (control) and the CR course (treatment) that are at the focus of this study. This comparison gives an overall snapshot of the average class format using the eight COPUS collapsed codes. Specifically, the COPUS codes are: *What students are doing*: Receiving R, Talking to class (STC), Student Working (SW), or Other (O); and *What the instructor is doing*: Presenting (P), Guiding (G), Administration (A), or Other (O). Individual codes were used as a reference.

Collapsed Codes ->Individual Codes

STUDENTS

R Receiving	L: Listening to instructor V: Viewing visuals
STC Talking to Class	AnQ: Student answering question posed by instructor SQ: Student asks question WC: Students engaged in whole-class discussion SP: Students presenting to entire class
SW Student Working	Ind: Individual thinking/problem solving WG: Working in groups on worksheet activity OG: Other assigned group activity Prd: Making a prediction about a demo or experiment TQ: Test or quiz
O Other	W: Waiting (instructor late, working on fixing technical problems) O: Other

FACULTY

P Presenting	Lec: Lecturing or presenting information RtW: Real-time writing D/V: Showing or conducting a demo, experiment, or simulation
G Guiding	FlUp: Follow-up/feedback on clicker question or activity PQ: Posing question to students (nonrhetorical) AnQ: Listening to and answering student questions to entire class MG: Moving through class guiding ongoing student work 1o1: One-on-one extended discussion with individual students
A Administration	Adm: Administration (assign homework, return tests, etc.)
O Other	W: Waiting (instructor late, working on fixing technical problems) O: Other

Figure 24 - COPUS Collapsed Codes (on left) as derived from COPUS individual codes (on right) (Smith et al. 2014a)

COPUS was modified in three ways: (1) codes related to clicker questions were not used because classroom response questions were not used in any of the classes; (2) all observations were recorded at 1-minute intervals instead of the COPUS original design of 2-minute intervals; and (3) COPUS collapsed codes were implemented for all observations. Collapsed codes contain eight codes in two categories. Three professionally trained observers rotated observation sessions approximately equally spaced throughout the semester. See Appendix B-COPUS Observer's Coding Form (Smith et al. 2014).

There were a total of twelve observations for the control course and twelve observations for the treatment course.

Table 30 - Classes observed using COPUS

	Semester	Number of classes observed	Enrollment
IE (control) course 1	Fall 2018	6	59
CR (treatment) course 1	Fall 2018	6	171
IE (control) course 2	Spring 2019	6	59
CR (treatment) course 2	Spring 2019	6	169

In order to merge the recorded data generated by the two different observers for each minute of the same class, the following method was used: (1) for each code, the total number of times *both* observers marked that code was added up, and (2) this sum was divided by the total number of codes shared by *both* observers (Smith et al. 2013b). The key point is that a code needed to be indicated by *both* observers in order to be included in the tally. This resulted in pie chart percentages of behavior in the classroom.

Looking at the averages for the IE (control) course it can be seen that *both* a lecture format and an active learning format were utilized in the instructional delivery of the course. On average, in the IE course, students were receiving-R about 68% of the time and the instructor was presenting-P about 61% of the time. Student-centered behaviors occurred, as indicated by COPUS codes: students talking-STC and student working-SW, during 13% and 16% of the class time on average. In addition, the instructor was guiding-G about a quarter (24%) of the total class time.

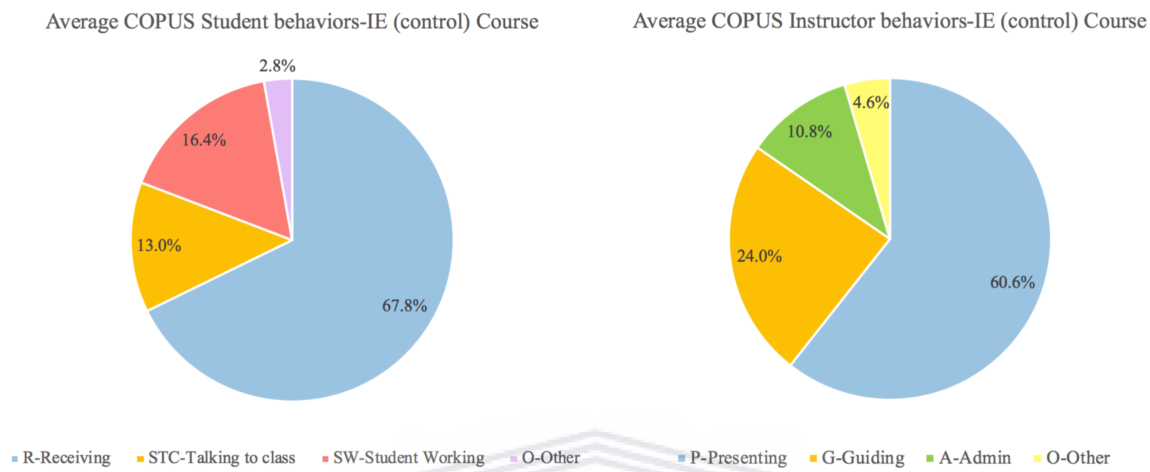


Figure 25 - Average COPUS behaviors - IE (control) course, Students (left), Instructor (right)

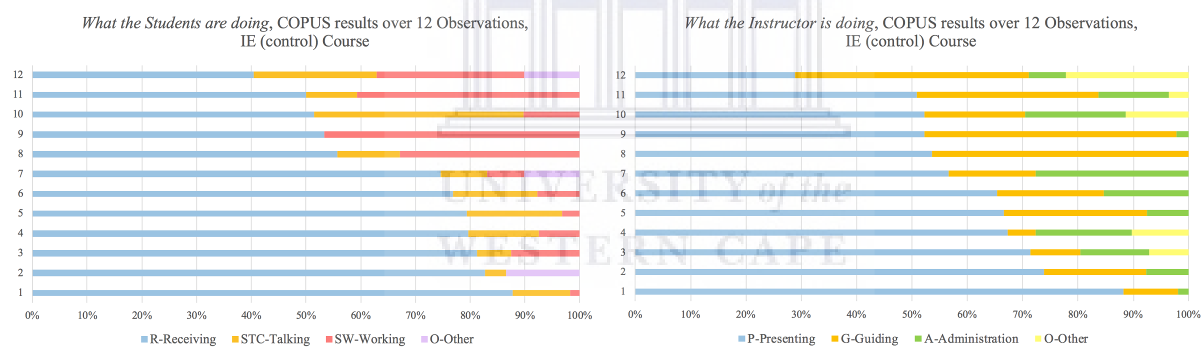


Figure 26 - COPUS Instructor codes (left), Student codes(right), IE (control) course, Average Level of Engagement 2.61 out of 3

In the CR (treatment) course, on average the students were receiving-R 57% of the class time and the instructor was presenting-P about 55% of the class time. Student-centered learning was implemented, as indicated by the COPUS behavior codes: students talking-STC and students working-SW, for 13% and nearly 30% of the average class time. The instructor was guiding-G the students 37% of the total class time.

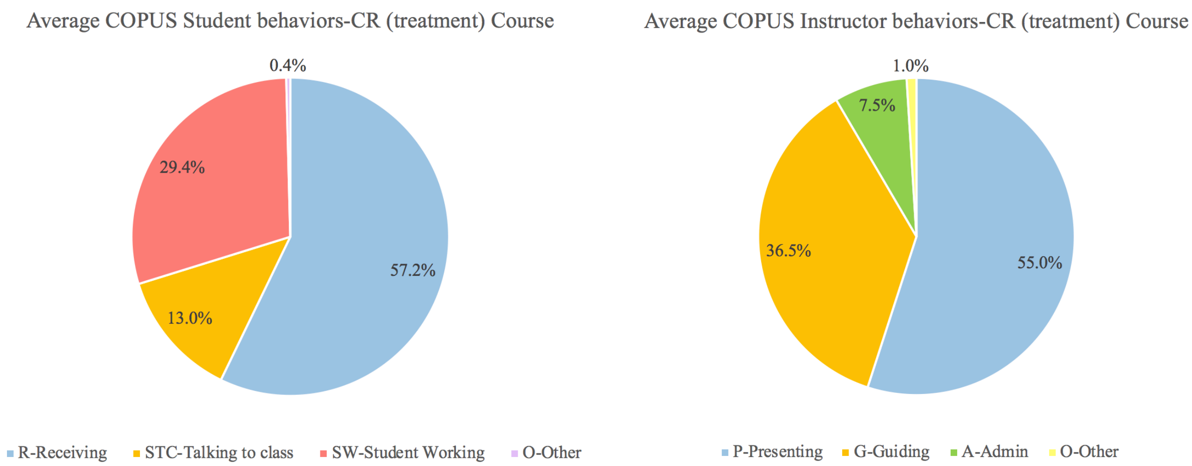


Figure 27 - Average COPUS behaviors – CR (treatment) course, Students (left), Instructor (right)

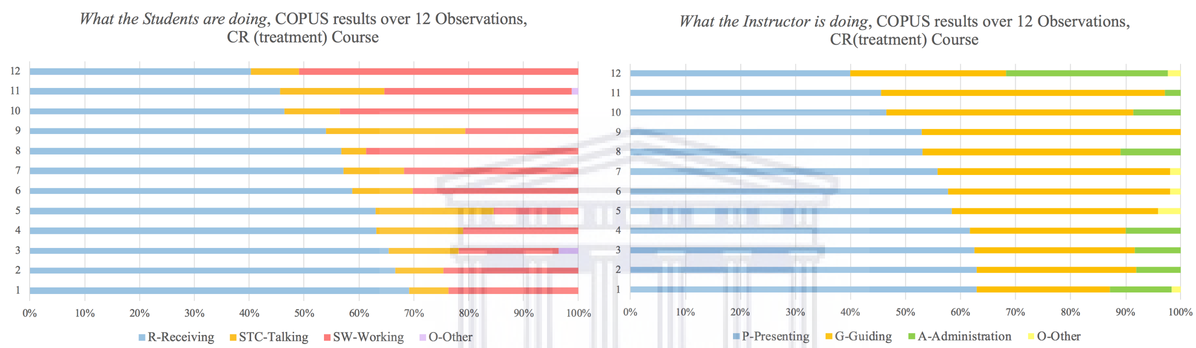


Figure 28 - COPUS Instructor codes (left), Student codes (right), CR (treatment) course, Average Level of Engagement 2.82 out of 3

>>>Significant Result 9. As measured by the COPUS observing protocol instrument, the two groups in this study, the IE (control) course and the CR (treatment) course, experienced both lecture-based, instructor-centered learning and active, student-centered learning as regular course formats, where traditional (T) learning is indicated by the paired COPUS codes: instructors presenting-P and students receiving-R. On the other hand, interactive engagement (IE), or active learning, is indicated by a cluster of three COPUS behavior codes: students talking-STC and students working-SW, and the instructor guiding-G.

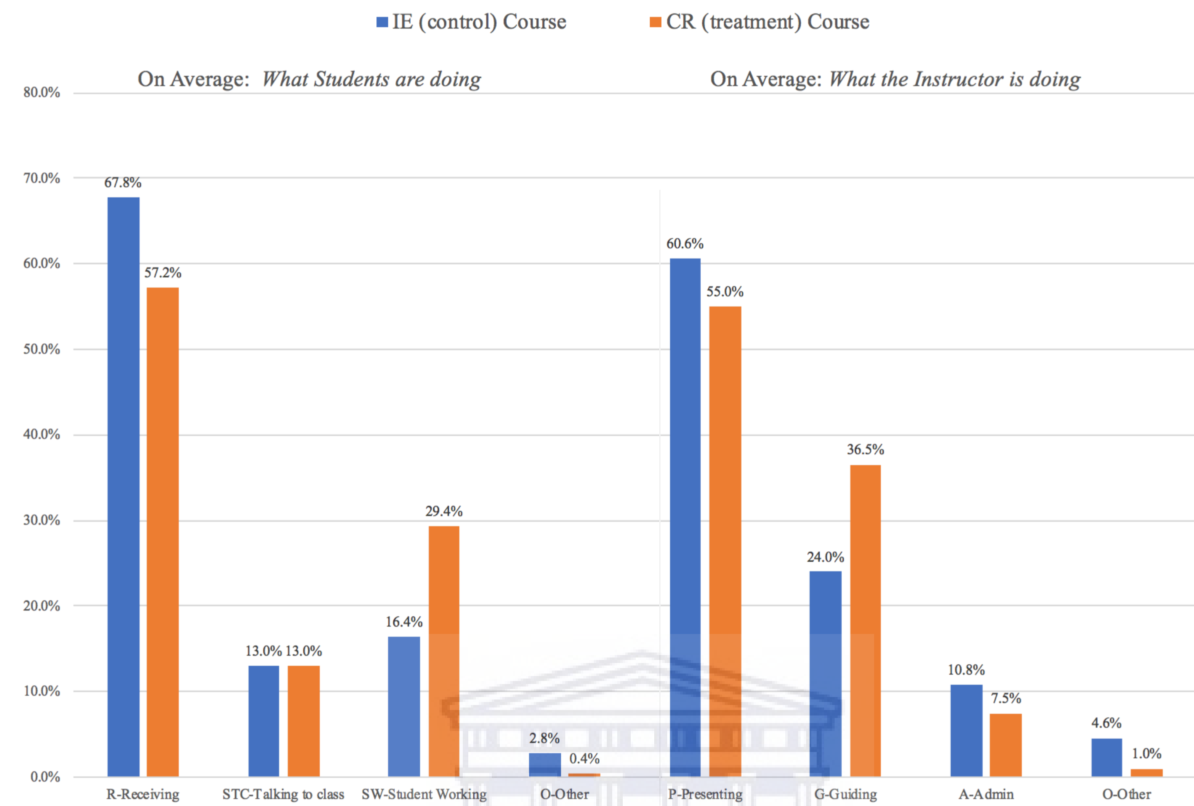


Figure 29 - COPUS observation instrument, average behavior of students and instructor, IE (control) course on left; CR (treatment) course on right

Table 31 - Comparing the average COPUS behavior codes of the two groups in the study

	STUDENTS IE (CONTROL) COURSE				INSTRUCTOR IE (CONTROL) COURSE			
	R-Receiving	STC-Talking to class	SW-Student Working	O-Other	P-Presenting	G-Guiding	A-Admin	O-Other
1	51%	38%	10%	0%	54%	46%	0%	0%
2	56%	11%	33%	0%	52%	45%	2%	0%
3	88%	11%	2%	0%	88%	10%	2%	0%
4	77%	15%	8%	0%	67%	26%	8%	0%
5	79%	17%	3%	0%	74%	18%	8%	0%
6	40%	22%	27%	10%	29%	42%	7%	22%
7	75%	8%	7%	10%	52%	18%	18%	11%
8	83%	4%	0%	13%	71%	9%	13%	7%
9	80%	13%	7%	0%	57%	16%	28%	0%
10	50%	9%	41%	0%	51%	33%	13%	4%
11	81%	6%	13%	0%	67%	5%	17%	10%
12	53%	0%	47%	0%	65%	19%	15%	0%
Average	68%	13%	16%	3%	61%	24%	11%	5%

STUDENTS CR (TREATMENT) COURSE	INSTRUCTOR CR (TREATMENT) COURSE

	R-Receiving	STC-Talking to class	SW-Student Working	O-Other	P-Presenting	G-Guiding	A-Admin	O-Other
1	63%	16%	21%	0%	46%	51%	3%	0%
2	46%	10%	43%	0%	58%	40%	0%	2%
3	67%	9%	25%	0%	56%	42%	0%	2%
4	69%	7%	24%	0%	58%	38%	0%	4%
5	63%	22%	15%	0%	53%	36%	11%	0%
6	57%	5%	39%	0%	53%	47%	0%	0%
7	40%	9%	51%	0%	47%	45%	9%	0%
8	65%	13%	18%	4%	63%	24%	11%	2%
9	54%	25%	21%	0%	63%	29%	8%	0%
10	59%	11%	30%	0%	62%	28%	10%	0%
11	57%	11%	32%	0%	63%	29%	8%	0%
12	46%	19%	34%	1%	40%	28%	29%	2%
Average	57%	13%	29%	0%	55%	37%	7%	1%

Although the percentages of students R-receiving and the instructor P-presenting are comparable for the two groups in this study, there are two behavior codes that differ significantly: students working-SW and instructor guiding-G. **>>> Significant Result 10.** On average, students in the course with increased cultural responsiveness (CR), or the treatment course, were working-SW nearly *twice* as much as the students in the IE (control) course (29.4%, 16.4% respectively). This result is *clearly statistically significant* of medium effect and confirmed by a Ranked T-test correlation with p-value < 0.00001 and Cohen's d of 0.754.

Comparing the average COPUS profiles between the two groups, it can be seen there is an increase of the instructor guiding-G in the CR course by over 54% (37%, 24% respectively). **>>> Significant Result 11.** In the course with increased cultural relevancy (CR) a second clear behavioral difference is that the instructor was *guiding*-G (54%) more often than in the IE (control) course. This result is *clearly statistically significant* of small effect and confirmed by a T-test correlation with p-value < 0.00001 and Cohen's d of 0.347.

These two actions in the treatment course: *students working more* and *instructor guiding more* are the most important behavioral differences between the course formats as measured by the COPUS observation protocol tool. Specifically, this result answers (at least in part) the question of how knowledge acquisition is different for the participants in the course with increased cultural relevancy (CR).

Additionally, statistically speaking, there is *no significant relationship* between course format and instructor presenting-P or students receiving-R (p-values 0.47 and 0.95 respectively). Which is another way of saying that both courses had approximately the same amount of lecture-type class time. One surprising result here is that students in the IE (control course) had slightly higher values for talking in class-STC than the students in the treatment course as measured by a T-test with a *clearly significant* p-value of 0.0004 and small effect size of 0.291.

Table 32 - Details of the statistical relationship between most relevant COPUS codes

The CR (treatment) course tends to have higher values for Students Working-SW than IE (control) course.						
Ranked T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	5.10726E-19				
Effect Size (Cohen's d)	Medium	0.754				
Difference Between Averages (IE–CR)		-0.593				
Confidence Interval of Difference		-0.729 to -0.458				
	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
CR (treatment) Course	300	1.0	1.0	305.0	0.916 to 1.12	0.9
IE (control) Course	300	0.0	0.4	127.0	0.332 to 0.514	0.8
The CR (treatment) course tends to have slightly higher values for Instructor Guiding-I-G than the IE (control) course.						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	2.55378E-05				
Effect Size (Cohen's d)	Small	0.347				
Difference Between Averages (IE– CR)		-0.303				
Confidence Interval of Difference		-0.444 to -0.163				
	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
CR (treatment) Course	300	2.0	1.2	366.0	1.12 to 1.32	0.9
IE (control) Course	300	1.0	0.9	275.0	0.819 to 1.01	0.9
There is no statistically significant relationship between COURSE and Instructor Presenting-I-P						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Not significant	0.474386279				
Effect Size (Cohen's d)	No relationship	0.0585				
Difference Between Averages (IE–CR)		0.0467				
Confidence Interval of Difference		-0.0814 to 0.175				
	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
IE (control) Course	300	2.0	1.5	449.0	1.41 to 1.59	0.8
CR (treatment) Course	300	2.0	1.5	435.0	1.36 to 1.54	0.8
There is no statistically significant relationship between COURSE and Students Receiving-ST-R						
Ranked T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Not significant	0.945569801				
Effect Size (Cohen's d)	No relationship	0.00559				
Difference Between Averages (IE–CR)		0.0133				
Confidence Interval of Difference		-0.0658 to 0.0924				
	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
IE (control) Course	300	2.0	1.8	544.0	1.76 to 1.87	0.5
CR (treatment) Course	300	2.0	1.8	540.0	1.74 to 1.86	0.5
The IE (control) course tends to have slightly higher values for Students Talking in class-ST-STC than the CR (treatment) course.						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	0.000403214				
Effect Size (Cohen's d)	Small	0.291				
Difference Between Averages (IE–CR)						
Confidence Interval of Difference		0.105 to 0.362				
	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
IE (control) Course	300	0.0	0.7	224.0	0.650 to 0.843	0.9
CR (treatment) Course	300	0.0	0.5	154.0	0.428 to 0.599	0.8

5.3.1.2 Level of Engagement

COPUS observers recorded '*level of engagement'* over each one-minute interval of the 50-minute class for each observing session. The categories for 'level of engagement' were defined as follows: low (0-20% of the students engaged); medium (21-79% of the students engaged); or high (80-100% of the students engaged) (Smith et al. 2013b). A weighted average was taken between the observers' engagement ratings, with the scoring rubric of low-1, medium-2, and high-3.

Results here are as follows. Overall, the average engagement for the treatment course was 2.82, as compared to the IE course which scored an average 2.61. **>>> Significant result 12.** The course with increased culturally relevant (CR), or the CR course, was found to have a *higher average level of engagement* as indicated by the COPUS observers' score of 'level of engagement' (2.82 versus 2.6, CR and IE respectively). Statistically speaking the *CR course tends to have higher values for level of engagement* than the IE course as measured by a Ranked T-test with p-value < 0.00001 and a Cohen's d of 0.742. This result is *clearly significant* and of *medium* effect size. Note on the table below the two observers' score of engagement has been summed over 1 to 6-point scale with low engagement scored as '1', medium engagement scored as '2', and high engagement coded with a '3' for each observer. On this scale the CR (treatment) course has an average engagement of 5.7 and the IE (control) course scored 5.1 on average. These observations reflect a 0.6-point difference or almost a 12% increase.

Table 33 - COPUS results for Level of Engagement, a clearly significant relationship between Engagement and Course Structure

Ranked T-Test	Basic	Advanced
Statistical Significance (P-Value)	Clearly significant	1.85E-18
Effect Size (Cohen's d)	Medium	0.742
Difference Between Averages (106 – 107)		-0.573
Confidence Interval of Difference		-0.708 to -0.439

	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
CR (treatment) course	300	6.0	5.7	1,701.0	5.59 to 5.75	0.7
IE (control) course	300	5.0	5.1	1,529.0	4.99 to 5.20	0.9

Furthermore, there is a more consistent higher level of engagement in the CR (treatment) course as indicated by ten out of twelve classroom observations (83%) had a higher level of engagement than in the IE course.

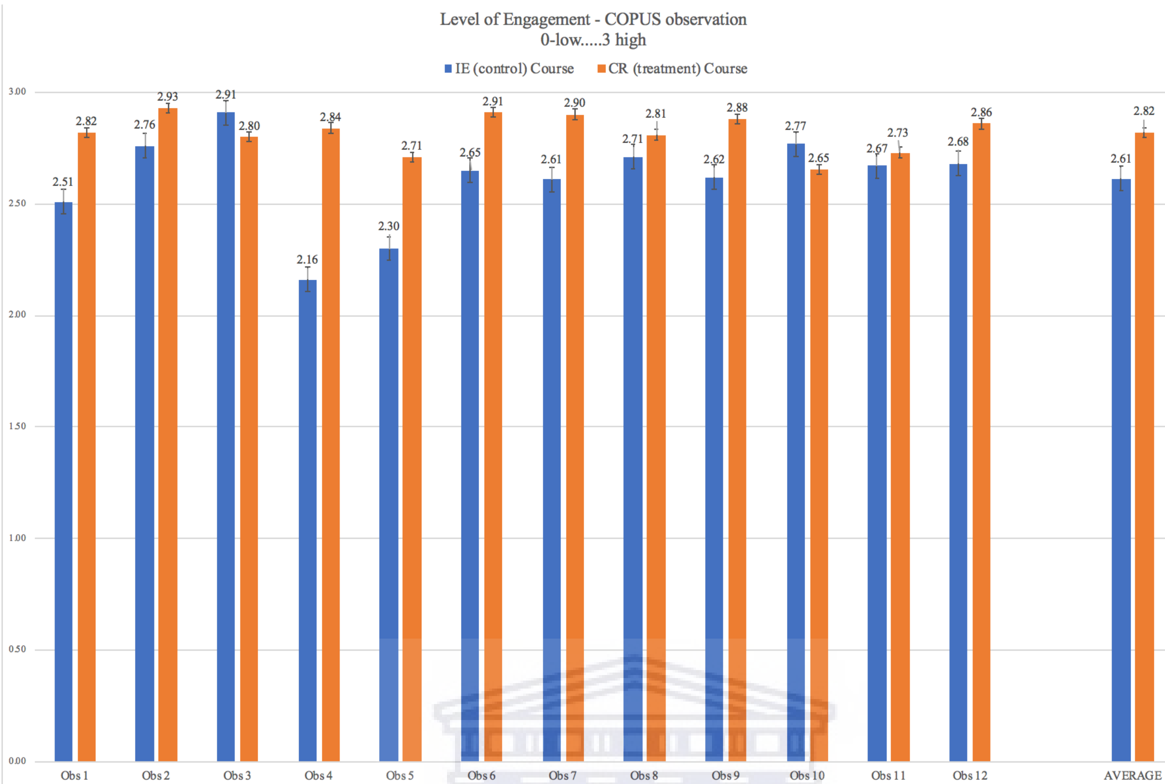


Figure 30 - Level of Engagement as recorded per minute by COPUS observers, 12 Observations, IE (control) course and CR (treatment) course, Average class engagement, 1-low, 2-medium, 3-high

In addition to level of engagement being correlated to course structure, other statistically significant correlations with level of engagement were found to be with: student working-SW, time, instructor guiding-G. Both of these variables were found to have *clearly significant* statistical values as indicated by p-values < 0.00001. These findings are consistent with the previously stated results of increased amounts of students working-SW and instructor guiding-G in the CR course (Result 3).

Table 34 - COPUS data showing a strong positive correlation between level of engagement and students working-SW

Students Working-SW is strongly positively correlated with Level of Engagement		
Ranked Correlation	Basic	Advanced
Statistical Significance (P-Value)	Clearly significant	p < 0.00001
Effect Size (Spearman's Rho)	Large	0.553811
Confidence Interval of Effect Size		0.496 to 0.607
Sample Size		600

Instructor Guiding-I-G is positively correlated with Level of Engagement		
Pearson's Correlation	Basic	Advanced
Statistical Significance (P-Value)	Clearly significant	p < 0.00001
Effect Size (Pearson's r)	Medium	0.396338
Confidence Interval of Effect Size		0.327 to 0.462
Sample Size		600

Statistical correlation tests found that instructor administration-A is *negatively correlated* with engagement (p-value < 0.00001 and Spearman's rho -0.324). This makes sense that students are generally less engaged when receiving schedule updates or homework logistics. Likewise, students doing other-O was found to have a *subtle negative correlation* with engagement (p-value < 0.00001 and Spearman's rho -0.234), along with instructor doing other-O (p-value is 0.00001 and Spearman's rho -0.178). This makes sense, for example, if students are waiting because of technical difficulties, this leads to lower engagement. Students talking in class-STC was found to have a *subtly positive correlation* with level of engagement (p-value of 0.0009 and Spearman's rho 0.135). *No significant statistical* relationship was found between level of engagement and the following: students receiving-R (p-value of 0.66) and instructor presenting-P (p-value of 0.868).

In summary, to return to the two key questions concerning the COPUS data:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*-> Yes. Students in the course with increased culturally responsive (CR) pedagogy were more engaged than students in the IE (control) course as perceived by the COPUS observers record keeping of 'level of engagement' with almost a 12% increase in the CR course engagement as compared to the IE course. See Significant Result 12.

- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?* -> Using the COPUS instrument observers recorded two distinctly more prominent behaviors in the CR course as compared to the IE (control) course: students working-SW nearly *twice* as much, and the instructor guiding-G over *50% more* in the CR course than in the IE course. See Significant Results 10 and 11. Furthermore, statistical analysis confirmed that the level of engagement is significantly and positively correlated to both of these behaviors. Therefore, it follows that based on the results of the COPUS profiles, culturally inclusive curriculum and teaching strategies increase classroom engagement.

Table 35 - Summary of Assessment Outcomes of COPUS data, two key questions: more engaging and how

Instrument -COPUS	*More Engaging for students in CR course?*	*How does increased CR affect knowledge acquisition?*
	✓ Result 12	✓ Result 10
		✓ Result 11
Note: Result 9 establishes that both course formats include traditional and active learning deliveries.		

Table 36 - Summary of Significant Results - Engagement gains based on COPUS data

Assessment Instrument - COPUS Observation	Ref. page	Increased engagement in CR course	How CR affects learning
Significant Result 9 *All courses in this study experienced both traditional learning (T) and active learning (A) as regular course formats*	p. 98		x
Significant Result 10 *Students in the CR course were working-SW nearly twice as much as the students in the IE (control) course.*	p. 100	x	x
Significant Result 11 *The instructor was guiding-G 54% more often in the CR course than in the IE (control) course.*	p. 100	x	x
Significant Result 12 *The CR course had a higher average level of engagement as indicated by the COPUS observers' score of 'level of engagement' than the IE (control) course.*	p. 102	x	x

5.3.2 Student Surveys

Anonymous online student surveys were designed and delivered as one of the assessment instruments in this study. Within twenty-four hours after the class an online survey was available for students to complete. Links to the survey were posted in multiple locations. Response rates for surveys were on average 45% for the control course and 49% for the treatment course. These response rates are above national survey response rates for higher education surveys at approximately 33% and 22% (Nulty 2008; Sax, Gilmartin, and Bryant, 2003).

Table 37 - IE (control) Course - Survey Participation Numbers

Control	# surveys	# responses	Response Rate	total # students
not bored	13	385	50%	118
excited	13	384	50%	118
focused	13	381	50%	118
time quick	13	381	50%	118
night sky	3	56	32%	118
confident comm	7	191	46%	118
learned new	10	264	45%	118
science diff	10	265	45%	118
see world	10	265	45%	118
sense of belong	7	176	43%	118
pictures	7	127	31%	118
curious	8	191	40%	118
recommend	13	379	49%	118
multiple perspectives	3	105	59%	118
Average	9.3	254	45%	118

Table 38 - CR (treatment) Course - Survey Participation Numbers

Treatment	# surveys	# responses	Response Rate	total # students
not bored	16	1519	55%	340
excited	16	1520	55%	340
focused	16	1522	55%	340
time quick	16	1514	54%	340
night sky	9	657	43%	340
confident comm	10	829	49%	340
learned new	13	1099	50%	340
science diff	12	972	48%	340
see world	12	977	48%	340
sense of belong	11	888	47%	340
pictures	9	609	40%	340
curious	12	852	42%	340
recommend	16	1508	55%	340
multiple perspectives	9	691	45%	340
Average	12.6	1083	49%	340

The assessment instrument of anonymous student surveys was implemented and analyzed to produce empirical data on and insights into the following key questions:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*
- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?*

5.3.2.1 Overall Survey Trends

Preliminary statistical analysis of the anonymous student survey data yields interesting results. There were 1,931 responses in all which includes: 391 for the IE course, and 1,540 for the CR (treatment) course. Note for the 'bored' question, the inversed average was used in order to calculate a meaningful average across all questions.

For the IE (control) course, the highest ranked positive survey statements were: 'I enjoyed learning about the night sky in this activity' (7.91), 'I learned something new' (7.84), and 'I liked that this activity used pictures to explain the topic' (7.76) with an overall average of 6.92 out of 10.

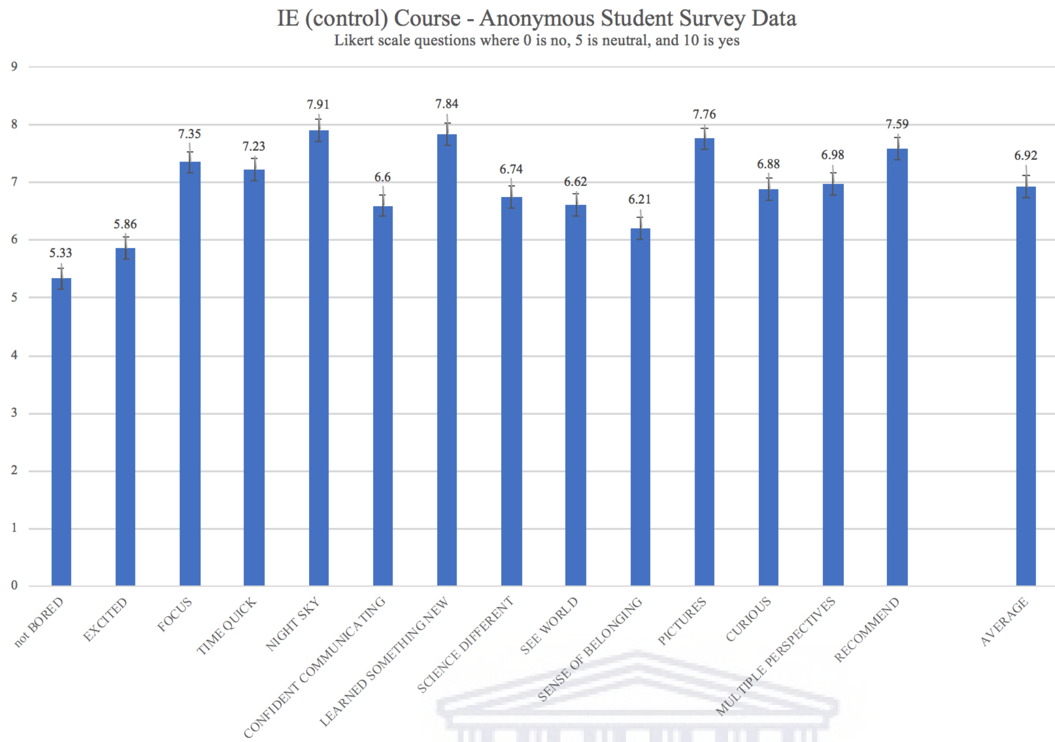


Figure 31 - IE (control) Course Survey Data, Positive response questions; Standard error bars shown.

For the CR (treatment) course, the top-rated positive survey statements in the CR course were: 'I liked that this activity used pictures to explain the topic' (8.1), 'I learned something new' (7.9), and 'I recommend this activity '(7.7). The overall survey average for the CR course for all survey questions was of 7.16 out of 10.

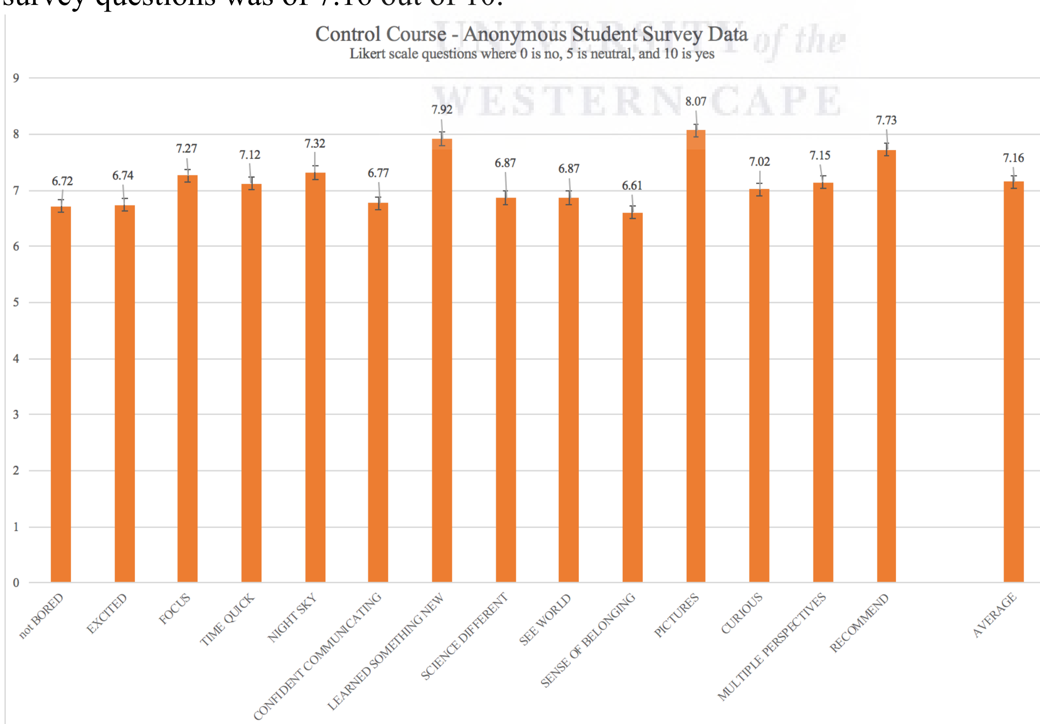


Figure 32 - CR (treatment) Course -Survey Data, Positive response questions; Standard error bars shown.

A few relevant observations are as follows:

(1) In 78.5% (eleven out of fourteen) of the survey questions, the CR (treatment) course responded with higher positive responses than the IE course. This led to a higher overall average positive rating in the CR course 7.16 as compared to the IE course 6.92, both out of 10.

(2) Between the two groups, many of the responses were very similar in ratings, but there were a few questions that the responses varied significantly with course structure. Specifically, the survey statements in which responses were most different between the two groups in this study were: During this activity 'I felt (not) bored' (difference 1.39); 'During this activity I felt excited' (difference 0.88); and 'Participating in this activity made me feel more a sense of belonging in this class' (difference 0.4). Apparently, the students in the CR (treatment) course were 'less bored', 'felt excited', and had a greater 'sense of belonging' than students in the IE (control) course as self-reported on anonymous class surveys.

(3) The IE (control) course scored a much higher positive rating for one of the survey questions. Specifically, the question related to: learning about the night sky, 'I like that this activity had to do with the night sky', scored 7.91 (IE course) and 7.32 (CR course) respectively.

(4) Consistently highly ranked positive responses for both the IE course and the CR course were: 'I liked that this activity used pictures to explain the topic' 7.8 (IE-control) and 8.1 (CR-treatment); 'I learned something new' 7.8 (IE-control) and 7.9 (CR-treatment); 'How likely are you to recommend this class', scored 7.6 (IE-control) as compared to 7.7 (CR-treatment); and 'I like that this activity had to do with the night sky', scored 7.91 (IE-control) and 7.32 (CR-treatment).

(5) Although the highest positive ratings by question have similar averages for both the IE (control) and the CR (treatment) courses 7.9, 7.8, 7.76 (IE-control) and 8.1, 7.9, 7.7 (treatment), the low ratings show more extreme lows in the IE (control) course. In particular, the lowest low ratings by question in the IE course were: 5.33, 5.86, 6.02. Compared to the lowest lows of 6.60, 6.72, 6.74 in the CR course. This is interesting because it shows that although both groups had a significant degree of class satisfaction, when dissatisfaction existed, the IE (control) course participants tended to be more dissatisfied than the CR (treatment) course.

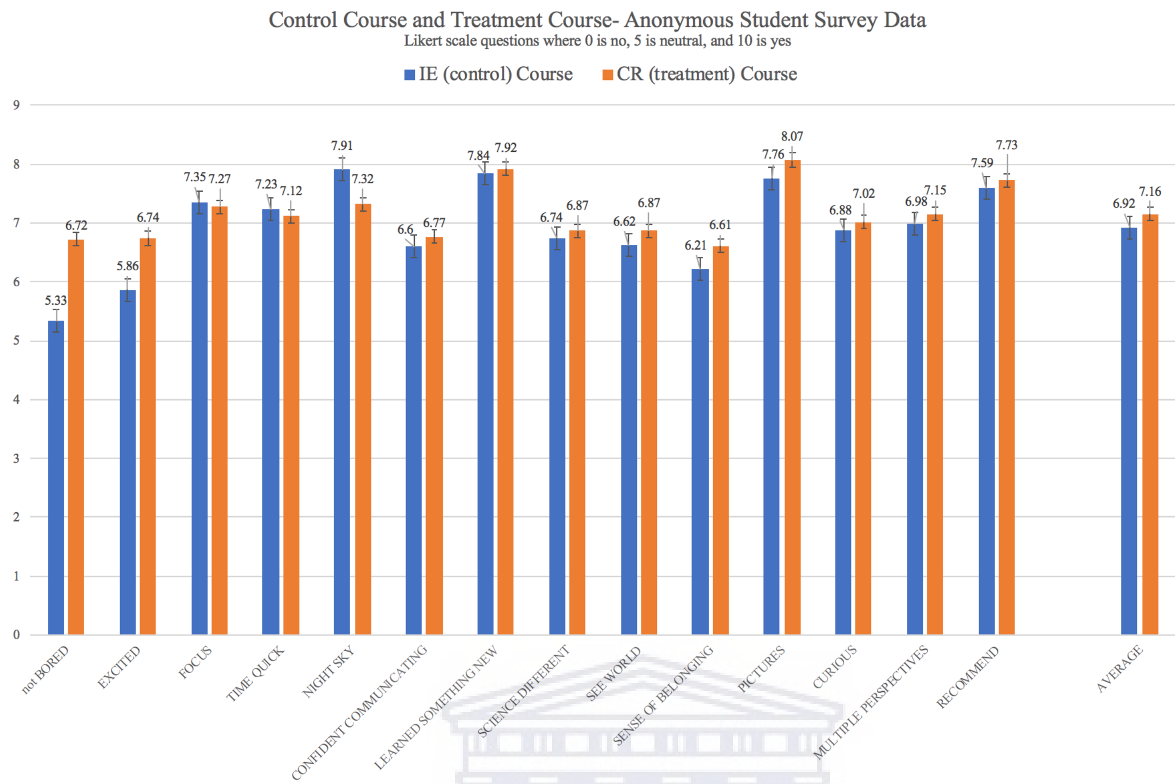


Figure 33 - IE (control) Course and CR (treatment) Course, Survey Data

When the survey data for both groups was combined, the whole group average across all survey questions is 7.10. In light of this, it can be seen that the following questions rank above average (in descending order): 'used pictures' (7.92); 'learned something new' (7.9); 'recommend' (7.7); 'night sky' (7.36); 'felt focused' (7.29); 'curious to learn more' (7.22); 'time went by quickly' (7.14); and had 'multiple perspectives' (7.12).

Table 39 - Survey Data Combined, Both IE (control) course and CR (treatment) course, 1904 survey responses max. 713 survey min. variations depend on question

Survey Keyword	Sample Size	Median	Average	Confidence Interval of Average	Standard Deviation	Minimum
PICTURES	849 of 849	8	7.92	7.786 to 8.061	2.04	0
LEARNED SOMETHING NEW	1,363 of 1,363	8	7.9	7.793 to 8.016	2.1	0
RECOMMEND	1,887 of 1,887	8	7.7	7.605 to 7.796	2.12	0
NIGHT SKY	713 of 713	8	7.36	7.183 to 7.546	2.47	0
FOCUS	1,903 of 1,903	8	7.29	7.184 to 7.388	2.26	0
CURIOUS	1,077 of 1,077	7	7.22	7.082 to 7.349	2.23	
TIME QUICK	1,895 of 1,895	7	7.14	7.035 to 7.253	2.42	0
MULTIPLE PERSPECTIVES	796 of 796	7	7.12	6.981 to 7.268	2.06	0
SCIENCE DIFFERENT	1,237 of 1,237	7	6.84	6.713 to 6.970	2.3	0
SEE WORLD	1,242 of 1,242	7	6.81	6.686 to 6.942	2.3	0
CONFIDENT COMMUNICATING	1,020 of 1,020	7	6.74	6.603 to 6.879	2.24	0
EXCITED	1,904 of 1,904	6	6.56	6.454 to 6.669	2.39	0
SENSE OF BELONGING	1,092 of 1,092	6	6.54	6.400 to 6.674	2.31	0

NOT BORED	1,904 of 1,904	7	6.44	3.432 to 3.689	2.86	0
Average			7.11			

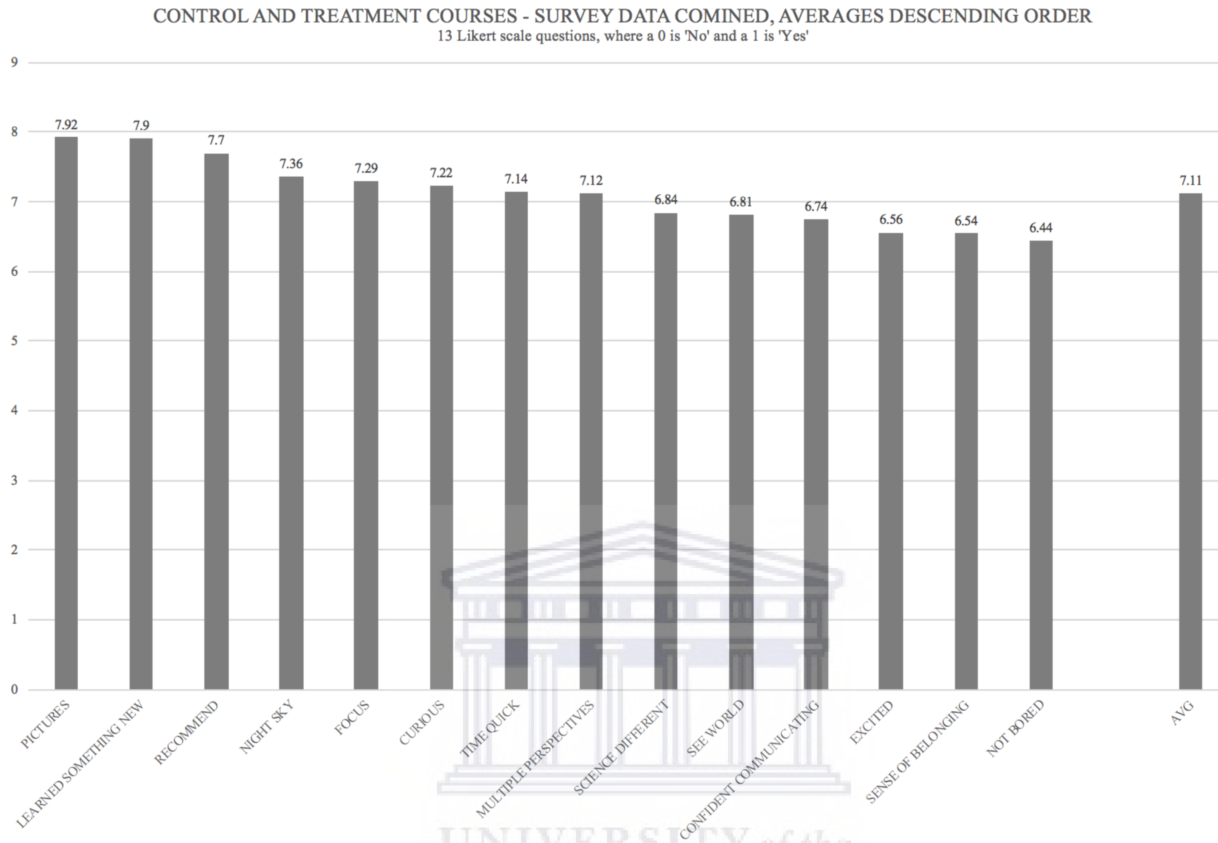


Figure 34 - IE (control) course and CR (treatment) course Combined Survey Data, 1931 total responses

Recall on these Likert scale questions a 0 is 'No', a 5 is Neutral, and a 10 is 'Yes'. For example, the highest ranked question across both groups reads: 'The pictures used in this activity helped me to understand the topic'. The second highest ranked question simply reads: 'During this activity, I learned something new.' See Appendix C-Survey Instrument.

The broad-brush stroke approach certainly gives some interesting comparisons, but a more rigorous analysis must be applied to determine statistical significance. 'Qualtrics Stats iQ' software was used to further analyze the survey responses. The analyses produced the following results. All statistical tests were done at the 95% confidence level.

Nearly all survey question responses were based on a 10-point Likert scale. This allowed for quantitative analysis based on comparison of the means and T-test statistics. The data was analyzed to find the p-value (determine significance) and the effect size (not dependent on sample size). If the p-value was less than 0.05, then the correlation was found to be "statistically significant". It is unlikely to be a coincidence. The effect size indicates whether a relationship is meaningful, regardless of the sample size. In general, for the T-tests effect size interpretation is as follows: > 0.8 large effect, > 0.5 medium effect, > 0.2 small effect, and < 0.2 trivial or no effect. Together the p-value and the effect size work to give a more practical indication of statistical significance. Note-one survey question was categorical. It read: "I find astronomy…'.

Answer choices were: 'Very interesting', 'Interesting', 'Boring', 'Hate it'. A correlation test with a Chi-squared analysis was used in this case.

5.3.2.2 Correlations with Course Structure as the Dependent Variable

>>> Significant Result 13. Students in the IE (control) course tended to have slightly higher values for 'felt bored' in class. The actual question states: 'During this activity, I felt bored'. This is a negative Likert scale question, meaning a lower number for the response is more positive. (Note, this is the only negative type Likert scale question on the survey.) The IE (control) course average for this question was 4.7 and the CR (treatment) course average was 3.3. Based on a T-test this is a *clearly significant* difference (p-value < 0.00001), with an effect size small (Cohen's d 0.496).

>>> Significant Result 14. Students in the CR (treatment) course tend to have slightly higher values for 'felt excited' than students in the IE (control) course. The actual question states: 'During this activity, I felt excited'. This is a positive Likert scale question, meaning a higher number for the response is more positive. The IE course average for this question was 5.9 and the CR course average was 6.7. Based on a T-test this is a *clearly significant* difference (p-value < 0.00001), with an effect size small (Cohen's d of 0.37).

>> Significant Result 15. Most students in the course with increased cultural responsiveness (CR), or the treatment course, self-identified at the beginning of the semester, as slightly less 'interested' in astronomy than most students in the IE course, as indicated by anonymous survey data of both courses. There is a *subtle but statistically significant* relationship between course structure and the question 'In general, I find astronomy'. This is a categorical type question, with response choices: 'Very interesting', 'Interesting', 'Boring', 'Hate it'. There were more students in the IE course that answered 'Very interesting' as compared to the CR course (52% control versus 45% treatment). More students in the CR course that responded 'Interested' (52% treatment versus 43% control). And finally, in the IE course 2% of students responded 'Hate it' as compared to 0% in the CR course. Apparently the IE course contained students of both extremes. This result is clearly significant based on a Chi-squared test (p-value < 0.00001) and effect size small (Cramer's V of 0.115).

> Significant Result 16. The CR (treatment) course tends to have *very slightly higher values* for the question: 'curious to learn' more than IE (control) course. The IE course average for this question was 6.9 and the CR course average was 7.3. Based on a T-test this is a *significant* difference (p-value of 0.0455), with an effect size trivial (Cohen's d of 0.181).

> Significant Result 17. The CR (treatment) course tends to have *very slightly higher values* for the question: 'sense of belonging' than IE (control) course. The IE course average for this question was 6.2 and the CR course average was 6.6. Based on a T-test this is a *clearly significant* difference (p-value of 0.0377), with an effect size trivial (Cohen's d of 0.177).

All other correlations with course structure yielded no statistically significant relationship based on inferential or hypothesis testing such as the T-test with p-values between 0.110 and 0.615. This is somewhat surprising because the survey questions with the highest positive rankings the differences by course structure were found to be not statistically significant. In other words, both groups gave fairly high positive ratings for these top questions and so the results were not statistically different. For example, 'used pictures' to explain had a p-value of 0.373, and 'learned something new' had a p-value of 0.615, but both had average ratings of 7.9 or higher.

Table 40 - Survey Results - Correlations with Course Structure

IE (control) course tends to have slightly higher values for 'felt bored' than CR (treatment) course						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	1.1968E-13				
Effect Size (Cohen's d)	Small	0.496				
Difference Between Averages (IE – CR)		1.39				
Confidence Interval of Difference		1.03 to 1.75				
Summary	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
IE (control) course	385	5.0	4.7	1,799.0	4.34 to 5.01	3.3
CR (treatment) course	1519	3.0	3.3	4,980.0	3.14 to 3.41	2.7
CR (treatment) course tends to have slightly higher values for 'felt excited' than IE (control) course						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	1.526E-09				
Effect Size (Cohen's d)	Small	0.37				
Difference Between Averages (IE – CR)		-0.873				
Confidence Interval of Difference		-1.15 to -0.594				
Summary	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
CR (treatment) course	1520	7.0	6.7	10,241.0	6.62 to 6.85	2.3
IE (control) course	384	5.0	5.9	2,252.0	5.61 to 6.12	2.5
There is a subtle but statistically significant relationship between Course Structure and the question: I find astronomy						
Chi-Squared Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	1.6607E-05				
Effect Size (Cramér's V)	Small	0.11472301				
Sample Size		1888				
CR (treatment) course tends to have very slightly higher values for the question: curious to learn more *than IE (control) course*						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Significant	0.04558664				
Effect Size (Cohen's d)	Trivial	0.181				
Difference Between Averages (IE – CR)		-0.402				
Confidence Interval of Difference		-0.796 to -0.00795				
Summary	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
CR (treatment) course	886	7.0	7.3	6,456.0	7.15 to 7.43	2.1
IE (control) course	191	7.0	6.9	1,315.0	6.52 to 7.25	2.6
CR (treatment) course tends to have very slightly higher values for the question: sense of belonging than IE (control) course						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	0.03768121				
Effect Size (Cohen's d)	Trivial	0.177				
Difference Between Averages (IE – CR)		-0.407				

Confidence Interval of Difference		-0.790 to -0.0233				
Summary	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
IE (control) course	204	6.0	6.2	1,266.0	5.85 to 6.56	2.6
CR (treatment) course	888	6.0	6.6	5,872.0	6.47 to 6.76	2.2

5.3.2.3 Correlations with Engagement as the Dependent Variable

Since a primary goal of this study focuses on engagement, it is important to use the survey data to dive deeper into the following questions with a focus engagement as the dependent or key variable:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?*
- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?*

To measure engagement with the survey data, the four questions on the survey that came from a published survey on engagement (Chung et al. 2016) were used. Specifically, the questions read: 'During this activity, I felt bored'; 'During this activity, I felt excited'; 'During this activity, I was focused on the things we were learning most of the time; During this activity, time went by quickly'. These questions are coded: '(not) bored'; 'excited'; 'focused'; and 'time quick'. Note that the (not) in front of the question 'bored' allows the negative response question to be averaged into the other questions as needed. These four questions appeared on every survey for both classes. There were 1,448 responses which included 1,156 from the CR (treatment) course and 292 from the IE (control) course. Overall the IE course average for this '(not) bored' question was 5.33, the CR course average was 6.75, for a combined group average of 6.46. The averages for the question 'excited' were 5.82 IE course, 6.80 CR course, and 6.60 average combined groups. The averages for the question 'focused' were 7.31 IE course, 7.40 CR course, and 7.32 average combined groups. And finally, the averages for the question 'time quick' were 7.23 IE course, 7.14 CR course, and 7.15 average combined groups. 'Not bored' is statistically higher for the CR course than for the IE course (p-value < 0.0001, Cohen's d 0.506). 'Excited' is lightly statistically higher for the CR course than for the IE course (p-value < 0.0001, Cohen's d 0.420).

The four survey questions focused on engagement were combined into a new variable simply called 'engagement'. Average responses were binned using the following rubric: less than or equal to 3 is a 'low engagement'; 3-6 is a 'medium engagement'; and greater than or equal to 6 is 'high engagement'.

Results of Combined Group by Engagement. **>> Significant result 18.** Students in the course with increased culturally responsive (CR) pedagogy were *slightly more engaged* than student in the control course as indicated by anonymous student survey data, sample size 1,439. The averages were: 6.44 control, 6.99 treatment, and 6.88 average for the combined groups. A statistical T-Test confirms this is a *clearly significant* result with a p-value of < 0.00001 and effect size Cohen's d of 0.301.

Table 41 - Survey Results, Engagement Correlated by Course

CR (treatment) course tends to have slightly higher values for Engagement than the IE (control) course.						
T-Test	Basic	Advanced				
Statistical Significance (P-Value)	Clearly significant	1.303E-06				
Effect Size (Cohen's d)	Small	0.301				
Difference Between Averages (IE – CR)		-0.55				
Confidence Interval of Difference		-0.770 to -0.329				
Summary						
Course Structure	Sample Size	Median	Average	Sum	Confidence Interval	Standard Deviation
CR (treatment) Course	1152	7.0	7.0	8,049.9	6.88 to 7.10	1.9
IE (control) Course	287	6.3	6.4	1,847.8	6.25 to 6.63	1.7

To address the question of how CR curriculum affects knowledge acquisition with respect to engagement, statistical correlation tests were run with engagement as the dependent or key variable.

Results of CR course by Engagement. **>>> Significant Result 19**. Students in the course with increased culturally responsive (CR) pedagogy, or the treatment course, felt the highest level of 'engagement' when the class activity included: 'multiple perspectives', the 'night sky', they 'learned something new', and the activity 'used pictures' to explain the topic among other factors. These results were statistically measured by correlation tests (mostly Pearson's correlation). All survey questions were found to be *strongly positively correlated* with engagement for the treatment course survey data. All correlations have p-values < 0.00001 and effect size large. These *clearly significant* correlations with the variable 'engagement' are listed here in ranked order (strongest first): 'multiple perspectives', 'night sky', 'learned something new', 'used pictures', 'science different', 'confident communicating', 'see the world', 'sense of belonging', 'recommend', and 'curious to learn more'.

5.3.2.4 Correlations with Satisfaction i.e. Recommend as the Dependent Variable

Finally, this study considered correlations with the variable that most represents satisfaction. In this survey that is the 'recommend' question. The survey question reads as follows: 'On a scale from 0 to 10, how likely are you to recommend this activity to a friend taking intro astronomy? Use the slider to move the gauge, for example: 0-Terrible waste of time..........10- Highly recommend'. This question appeared on every survey for both classes. It was coded as 'recommend'. There were 1,887 responses which included 1,508 from the CR (treatment) course and 379 from the IE (control) course. Overall the IE course average for this 'recommend' question was 7.59, the CR course average was 7.73, for a combined group average of 7.70.

- Will students find ASTR 101 more engaging if the content is more culturally relevant?

- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?*

On average both groups of students recommended their respective course at the nearly the same level however the CR course reported a slightly higher numerical value, (7.71 IE course, 7.75 CR course, average recommend of 7.74). However, this result was measure by a T-test with p-value 0.75 and effect size-Cohen's d of 0.0223, and determined not statistically significant.

Results of CR course by Recommend. *All* survey questions were found to be *strongly positively correlated* with key variable 'recommend' as indicated by p-values < 0.00001. Listed here in order of strength of the correlation (strongest first): 'engagement', 'multiple perspectives', 'used pictures', 'sense of belonging', 'night sky', 'see world', 'science differently', 'confident communicating', 'learned something new', and 'curious'. All of these survey questions had p-values < 0.00001and all but 'curious' had effect size large or equivalently Cohen's d 0.5 or larger. **>>> Significant Result 20**. Students in the course with increased cultural relevancy (CR), or the treatment course, were more likely to 'recommend' this course when: they 'felt engaged', the activity included 'multiple perspectives', 'used pictures', and they felt a 'sense of belonging' among other factors.

A brief summary of the survey data is as follows. Ultimately, the survey data in this study was used as an assessment instrument to measure the outcomes of the two key questions: *Will students find ASTR 101 more engaging if the content is more culturally relevant?;* and *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?*

Will students find ASTR 101 more engaging if the content is more culturally relevant?-> Yes. The best evidence to support this result based on the survey data is the following. Students in the course with increased culturally responsive (CR) pedagogy, or the treatment course, felt 'less bored' (Significant Result 13), 'more excited' (Significant Result 14), 'more curious' (Significant Result 16), more a 'sense of belonging' (Significant Result 17), and more 'engagement' (Significant Result18).

How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students? -> According to the results of the statistically analyzed anonymous student survey data the following results were found. Students in the course with increased culturally responsive (CR) pedagogy, or the treatment course, were more engaged when the activity included: 'multiple perspectives', the 'night sky', they 'learned something new', and the activity 'used pictures to explain the topic' (See Significant Result 19). Furthermore, it was found that students in the course with increased culturally responsive (CR) pedagogy, or the treatment course, were more likely to recommend the class if: they 'felt engaged', it had 'multiple perspectives', 'used pictures', and the student felt a 'sense of belonging' (See Significant Result 20). And surprisingly it was found that most students in the course with increased culturally responsive (CR) pedagogy, or the treatment course, self-identified as slightly less 'interested in astronomy' than most students in the IE (control) course (Significant Result 15).

Table 42 - Summary of Key Research Questions with Significant Results

Instrument	*...more engaging if the content is more culturally relevant?*	*...how does CR curriculum qualitatively affect knowledge acquisition?*
Survey-Correlations with Course Structure	✓ Result 13, Result 14, Result 16, Result 17	✓ Result 15
Survey-Correlations with Engagement	✓ Result 18	✓ Result 19
Survey-Correlations with Recommend	✓ Result 20	✓ Result 20

Table 43 - Summary of Significant Results - Survey data.

Assessment Instrument - Surveys	Ref. page	More engagement in CR course	How CR affects learning
Significant Result 13 *Students in the IE (control) course were more likely to feel bored in class compared to the CR course.*	p. 111	x	x
Significant Result 14 *Students in the CR course tend to feel excited more than students in the IE (control) course*	p. 111	x	x
Significant Result 15 *Students in the CR course started the semester with less interest in astronomy than students in the IE (control) course*	p. 111		x
Significant Result 16 *CR course students are more curious to learn than the IE (control) course students.*	p. 111	x	x
Significant Result 17 *Students in the CR course felt a slightly greater sense of belonging than IE (control) course students.*	p. 111	x	x
Significant Result 18 *Students in the CR course were slightly more engaged than student in the IE (control) course as indicated by anonymous student survey data.*	p. 113	x	x
Significant Result 19 *Students in the CR (treatment) course felt more engaged when the class activity included: multiple perspectives, the night sky, they learned something new, and the activity used pictures to explain the topic among other factors.*	p. 114		x
Significant Result 20 *Students in the CR (treatment) course recommended this course when: they felt engaged, the activity included multiple perspectives, used pictures, and they felt a sense of belonging among other factors.*	p. 115		x

5.3.3 Interviews

The interview data and subsequent analysis was a measurement tool used to gather richer, qualitative data that could then be used to address the following questions more deeply:

- *Why did students in the culturally responsive (CR) course gain more content knowledge compared with students in the interactive engagement only (IE) course?*
- *How were underrepresented minority (URM) students positively affected by participating in the culturally responsive (CR) course?*

Ten students that had previously taken the course with increased cultural relevancy (CR), or the treatment course, were interviewed for an average of twenty-three minutes (minimum 13 minutes, maximum 36 minutes). The interviews were semi-scripted in order to allow for a more conversational, flexible format. The intended purpose of the interview was to elicit some rich and nuanced perspectives from the students especially in comparison to other university courses they may have taken. Participants included: freshmen to junior students; two transfer students, seven Minnesota permanent resident students, three international students; 50% male and 50% female; one non-traditional student; 10% underrepresented minority students (URM); and 40% students of color (including Asian and URM). Majors included: a Business major, an Undecided major, two Arts majors, five Science, Technology, Engineering, Math (STEM) majors, and one Social Science major.

Table 44 - Details of 'Down-the-Pipeline' Student Interviews, CR (treatment) course

Interviewee	Major	Time
1	Information Systems (IS)	23:58
2	Information Systems (IS)	21:13
3	Graphic Design	13:06
4	Computer Science (CS)	25:23
5	Cyber Security	14:58
6	Finance	19:30
7	Undecided	23:30
8	Anthropology	20:42
9	Film	33:00
10	Bio-medical	35:50

One perspective that was talked about by all interviewees was 'the way the course was taught'. Participants specifically mentioned the CR course was different from other courses taken. Many students talked about course delivery. They specifically mentioned traditional lecture-based college classes and how this standard course format was not engaging.

> *I actually was in a different class… I switched out of (it) because the first week I was there it was just …. he would teach on the content during the week and just do a quiz on the end of the week. And the first quiz I took I was like ...I can't concentrate. It was really frustrating. It was … not for me. So I saw this class and honestly...was not really thinking astronomy at first... But so glad that I did select it because I liked the way that you gave us many opportunities. You made learning fun for one thing. But you gave so many different opportunities to succeed..... Because some professors are more about just here's the content I want to teach to you. And here's the test. And when you have these extra opportunities to really show that you're engaged and you want to learn then that was really helpful for me.* (Interviewee 1)

> *The way you explain is very clear…that makes it a good quality because you actually start to understand the concepts more clearly because you're applying it…The activities are also a very big difference because we do them in class and it's easier to do the quizzes when we get home and also understand the concept. (In other courses) most of the times professors just usually assign homework and they might show an example but usually not. Like my security class. You just do it by*

> *yourself. You learn the concept through the book or the lecture, or both, and then you do it at home. That's it.* (Interviewee 2)
>
> *This is definitely a bigger class then I thought it would be. Initially I thought "Oh if I have some problems it's hard to approach the professor." I think the way you teach and all worksheets that you gave it is very helpful already. It's like as long as I come to class and I do the worksheet. I'll be able to finish the quiz if I listen. If I listen. If I don't listen, I would not know anything. If it's only lecture you don't get to do anything, you don't have anything to expect for the exam or quizzes. If we do it then we know that "Oh that's my problem." As I was doing the worksheet I know which part I don't understand and which part I know and which part I should work more on.* (Interviewee 10)

An additional insight was offered by many interviewees, that the 'instructor cares', as evident in the following quotes:

> *But look when I was in your class … like you seem genuinely… interested and happy to teach the class … I think that really helps (like) pay attention and people were actually interested because you're interested.* (Interviewee 7)

And a sense of inclusivity was mentioned, that learning was not just for people that came in with a lot of pre-existing subject knowledge, but for everyone:

> *I felt like when I did my first introductory computer class it just was like the weed-out class, either you know the material or you don't. And if you don't, might as well just leave now and change your major… For you (the CR course) it's just like if you don't know it, that's fine you can come in knowing nothing but you're going to learn new knowledge … no matter what. So that's what I looked forward to, and what I actually strived for because I didn't know much about astronomy.* (Interviewee 5)

And, "I think you're a great professor who clearly cares a lot" (Interviewee 9). A number of students specifically mentioned the class was 'fun'.

> *You gave me the opportunity to use some of my other skills that I have. You know being a musician ...and so kind of blending ..learning science and then ..some of my talents ...if you will... That was a lot of fun.* (Interviewee 1)
>
> *When you work with the group, even if you work by yourself, you still have the time to think about it all. Can you imagine going to Mars and then at the end you ask. What if there is only one way? …It makes you think further into the future... You understand it more and it just makes it more (like) fun, more interesting…But also you're still doing the activities of like you know learning the sky ...you know like the constellations ...you still have to do it but it's not only that ..you're also learning the fun part of it.* (Interviewee 2)

One student elaborated on this idea mentioning how when video design was used in other classes, it was individual based and founded on the premise "tell me what you know.. show straight facts" (Interviewee 5) as compared to the group video project in the CR course which was, "Show me what you know and have fun showing the knowledge" (Interviewee 5).

The interview conversations all mentioned class size being large. This led to many comments about the 'small group discussions'. All students interviewed agreed that the small group discussions were an asset.

> *First, I think discussions are great because. ..throughout the whole class if we don't have discussion we would not know anybody. Because it is a huge class and everybody kind of like just minds their own business. So I wouldn't of thought of talking to the person sitting next to me. …the discussion it really helps us to step out of our comfort zone and talk to people next to us and with all those funny questions like things that we never even thought about it.* (Interviewee 10)

They frequently viewed the small group discussions as positive because in such a large lecture course (~200 students) the students appreciated having the opportunity to hear 'many different perspectives'.

> *I mean .. you can kind of just get different perspectives. …different things like when we were talking about … 'Do you think there's other life out there.?' You know, I kind of like hearing what other people have to think about that. …if people are genuinely interested in the class and stuff, I feel like it's a good exercise because you can hear the other perspectives... Why do you think that you know?* (Interviewee 6)

> *…with two hundred students if you sit in another place the next time you get different perspective… There's different perspective the more people there are, everybody's different.* (Interviewee 2)

> *I think you can like bounce ideas off of other people because there was one girl in the class where we started talking about like the Mandela Effect. And like all that stuff in black holes and whatnot and then it was kind of fun. It's like you get to meet a bunch of new people that you know are interested in the topic as well. And it's not just like a class of 20 people that are just taking the general for the general not really learning anything.* (Interviewee 3)

One student voiced how intimidating the small group discussions were at first, particularly as an international student:

> *I don't really go and talk. Sometimes you get that sheet and then you have to do that group. You know you must... I have to go…But when you start talking to people they're really nice like they will talk back to you ...because they don't know you either ...you don't know them. It's a strange thing to not say hi you know.* (Interviewee 4)

Also mention by several interviewees was that the discussions had 'no specific answer'. Apparently this was a welcome change from the typical college course.

> *So also having activities and not being judged. That's another thing. There is no specific answer for like .. Would you like to go to Mars? You know when you could take this kind of survey. It makes you think….but think more broadly out of the box compared to when you don’t have specific questions.* (Interviewee 2)

Small group discussions were directly connected to a greater ‘sense of belonging’ as illustrated in the following quote:

> *I like to talk to your neighbor.....it kind of made it have a sense of belonging ...like you actually felt belonged because you were talking... If you didn't say we had to have a conversation with your neighbor. I wouldn't. We would help each other, so yeah that made me feel belonged.* (Interviewee 8)

Nearly all students interviewed spoke very highly of learning about the ‘night sky’ and constellations. They shared past experiences when they looked at the sky, some knowing the Big Dipper, but after the class they were able to: (1) know more advanced or fainter constellations, (2) know a deeper story of astronomical treasures found within the boundaries of certain constellations, and (3) felt confident communicating this knowledge of the sky after the class ended. One excited student talked about going to a dark sky area and seeing “one of the arms of the Milky Way” (Interviewee-3). Another mentioned how he could point out the stars to his girlfriend after taking the class. “I used to tell my girlfriend. ‘Do you know this is Orion... And then just like those blue stars...and red stars…’ It was so interesting that I even thought about buying a telescope….” (Interviewee 4). Another shared: “I will never look at the night sky the same ever again….anything I'm doing … if I'm outside and I'm seeing the stars it's like “Oh yes, I recognize that.” (Interviewee-1). Still another adds, “I would look up at the stars and like I'd recognize like the easy ones like the Big Dipper. … But now I can do Draco … And like Cepheus and all that fun stuff. ..” (Interviewee 3). And, “I definitely have a new respect for astronomers and... I will never look at the night sky the same ever again.” (Interviewee 1). Finally we hear the pure joy of applying the knowledge learned in class to the real night sky, “…after we learned the night sky. Of course I cannot see every constellation right away... Like I have to stand and it's cold. But Orion you can see it in the winter, right. It's a winter constellation. I stood outside and I was like… Oh my God this is Orion Now I know. I was so happy” (Interviewee 2). Two students shared that they were considering the astronomy major after taking this class. Reasons for taking the class were sometimes a prior interest in astronomy or sometimes to satisfy a general education credit. Here is an example of the first case:

> *I've always been intrigued by stars and I always would stare at the night sky when I was younger and I was like it's time to just know about it. I have the tools necessary and I'm in school. Let's just learn about it so that's why I chose it.* (Interviewee 5)

In some students, the interest in the night sky was counterbalanced by a negative view of math and science:

> *I have an interest with stars or something like that (like) it's just every time I look up I'm like I'm kind of interested in what's out there. So my image of it like I just wanted to know more. But like math-science I can't like it. It's a lot harder...I'm not very good at those subjects.* (Interviewee 8)

The student goes on:

> *I liked learning about the constellations. That kind of learning. I like the image that it provides in my head like. When I think about astronomy I'm like ok we are going to learn about stars. Just when you throw in the math they're like you know it just kind of it totally just takes my attention elsewhere. I just not interested in math. So then it just makes it harder.* (Interviewee 8)

The knowledge acquired in class regarding the night sky was also valued by several students because they continued to use it after the class ended:

> *Yeah, it kind of makes me want to go into the field (astronomy) a little bit but I don't know we'll see… it's pretty interesting I find myself looking up at the stars a lot more than I used to like just like refresh my memory I like to know which constellation is which and what not. So it's interesting.* (Interviewee 3)

Students in the CR course remembered the 'pictures'. Many students remembered the visual images of colorful nebulas. Described by one student:

> *The pictures were super cool.. Super vibrant colorful pictures …because it just like draws your attention… like this is cool and you see pictures and you're like that's what's out there… It's not just like black with stars… all of the stars and planets and all that stuff and all the ones with the light that kind of stretched out a little bit .. It was like ten thousand galaxies. I love that one. Yeah, that one really was super cool to me.* (Interviewee 7)

When asked what their favorite topic in the class was one student remarked:

> *Nebulas…just because they're fascinating to me. I've always been fascinated in nebulas … the colors is partly the reason why I am fascinated but it's just I don't know. It's strange and different.*(Interviewee 5)

Also:

> *It (the course) was really interesting… It really attracts your attention because you have a lot of visuals and a lot of stuff. And you may get some questions and may participate. You know these things (like) keeps me on the right track because sometimes if the lecture is too long I cannot focus.* (Interviewee 4)

The majority of students interviewed appreciated learning about the bigger, 'broader view of science in society' alongside of the astronomy content knowledge. A student explained:

> *I just realized that it's kind of like ..more broad. It's like a broad spectrum. There's a lot to learn. I always thought of science as being like chemistry and like that kind of stuff. But it's not, it's actually ...astronomy like stars and all that stuff. It's crazy. And I think it's a lot of fun. I've always wanted to take like science classes and math classes…* (Interviewee 3)

> *I just thought like well my life would be totally different without science. … I didn't know anything about gene editing about any of all that so that was really interesting to learn about and I just didn't know it existed.* (Interviewee 8)

> *I remember … you mentioned a question something about like you know if you were able to go to Mars and live there ... I mean that kind of stuff like that. … Some of this ethical stuff I like tying that stuff into it because I feel like there's more to astronomy than just you know that one piece of learning how the math and stuff works too... you know... equations.* (Interviewee 6)

> *You are applying it to the news like this is what's happening like with the planets that might potentially have life … without knowing the concepts you wouldn't understand the news either. You have to have some background in order to understand it but when you actually read it also sticks to your head. I still remember that ..because when you put the news it's happening right now in the real world. That's why I remember the concept. That's why it makes it more meaningful and useful.* (Interviewee 2)

The importance of practicing communication and how it leads to 'cultural fluency' was observed:

> *We have to have those soft skills because …you need to be able to interview and work with your employers and your future supervisors. You need to communicate with your colleagues your co-workers…I don't think that we have enough emphasis on communication in life in general. I mean you think about if people weren't on the Internet they would just talk to each other maybe we wouldn't have so many wars and maybe if you gain more understanding about other different people groups you might not have so many biases against them.* (Interviewee 1)

Another remarked:

> *I think you do a good job of trying to tie it into the class in a way that is ...that feels more sort of culturally relevant to the individual student. I think a lot of people are uninterested in science because there seems to be kind of a stigma around it. .. science as being boring, bland, and unimportant.* (Interviewee 9)

This same student went on, "I think it's really great that you're doing this. I think it's great to get the students more involved in general with how the classes are structured and how they are organized… should happen more…" Then adds, "The customer wants to know that the provider of their services has the best out for them. And being involved with them and talking to them this way…It's just good" (Interviewee 9).

One surprising theme that surfaced in the interviews was 'confidence communicating' especially in relation to the night sky. Here is an excerpt from a female STEM major interviewee:

> *I've always been good at science but I've never been confident enough to talk about it and now after this class.... I know for a fact that I could say something and it'd be correct. And if not, then I at least can look up the tools necessary to*

> *find if the answer is correct or not... I just feel more confident when I talk about things like that...* (Interviewee 5)

And from another female STEM major, "It makes us look smart… because of the worksheet and makes us like really learn and learn how to apply it.. So you have to know the knowledge and literally apply to it and it sticks with you." (Interviewee 10)

Both female STEM majors are students of color (URM plus Asian).

A very interesting theme that emerged from the interviews, the importance of learning and practicing 'critical thinking':

> *It's interesting to think from like a scientist point of view when you're trying to tell the class about the news ...then we know it's not a fake news, like if a professor that helps to validate this thing in telling us then we are like .. 'Oh no, the thing that I read on Facebook was totally false." ... We don't even know what's wrong and what's right on the news. ...especially from a science point of view. ..we don't.* (Interviewee 10)

One student mentioned how the idea of alien life goes against 75% of her family's belief system. She hadn't brought up the scientific viewpoint with them, yet.

> *You know (like) in my family they're kind of conservative a little bit I guess. But I would say, I'm from a very big family,....and like 75% of them I would say, don't believe in other life or anything. And they're like super against it. Like when you bring up aliens or anything else like that they're like, 'If it's not real, don't waste your time.* (Interviewee 7)

A few students specifically mentioned how deeply related these ideas are to the core of a person's identity. For example, in regard to the possibility of extraterrestrial life existing, "I mean especially as a religious person you don't really believe in this kind of stuff when you're growing up ...and then they don't tell you this kind of stuff...the people don't know. People don't." The interviewer: (It goes against religion in a way you're saying?) "Yeah it does" (Interviewee 2). "When you think about like what's out there and it's like it's endless...so it makes me think there's there are other life out there ...kind of thing like we can't be the only ones. It's like it's so interesting. It's like mind blowing…how we're so small compared to like all these big stars and other planets…What even is life...? It's crazy" (Interviewee 3).

All interviews were positive in tone. "I thought the class was actually really interesting. I thought it covered a lot of stuff that I had never even heard about before. I still find myself today thinking about the class because it was one of my favorites" (Interviewee 3). "So my experience in this class it was a lot of fun. It was actually one of my favorite classes I've taken" (Interviewee 1). "I've been recommending it to a lot of people to take it. Like my stepbrother I think he's coming to take classes here" (Interviewee 3). "I mean this class is great. I recommended it to a couple friends and they're actually in it right now" (Interviewee 5). "It was a great class like it is totally what I was like hoping for" (Interviewee 6). "I really enjoyed the class"(Interviewee 7)."I think you're a great professor who clearly cares a lot about that. I think that shows I think with such a large class and you obviously have a lot of experience with this because I think you do a good job of handling teaching your class like this and I would say it was definitely solid" (Interviewee 9).

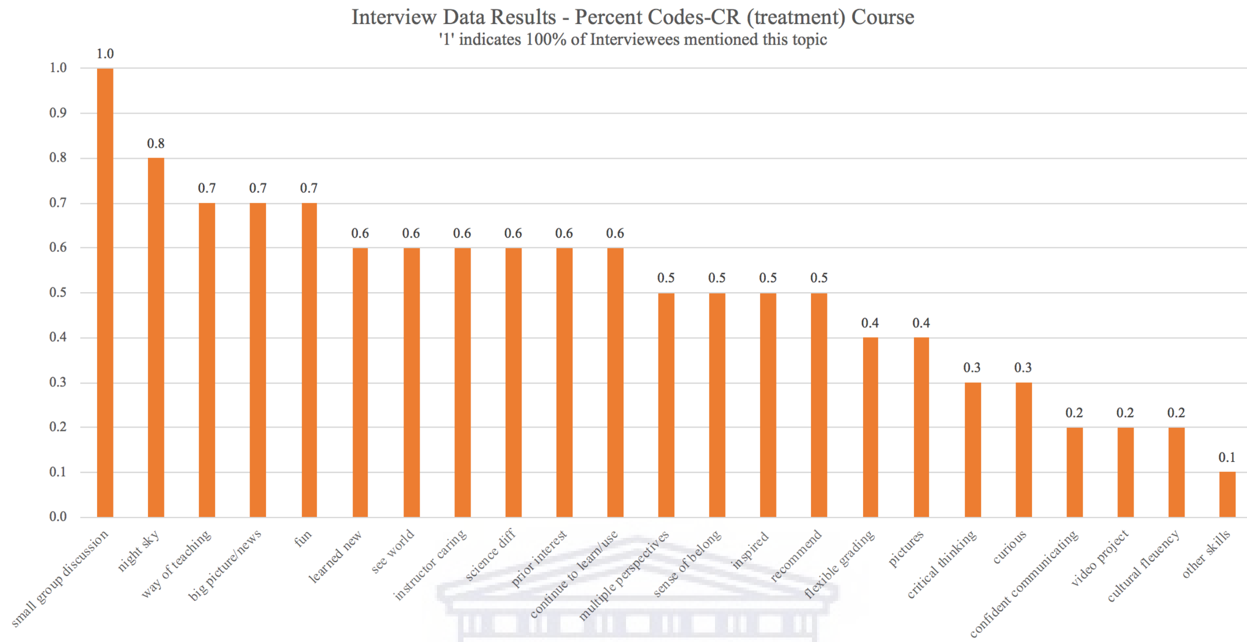


Figure 35 - Interview data- Categories averaged responses, ten participants from the CR (treatment) course, 'down the pipeline'.

Table 45 - Codes based on Interview Data of students previously in the CR (treatment) course

Code	Count	Average
small group discussion	10	1.0
night sky	8	0.8
way of teaching	7	0.7
big picture/news	7	0.7
fun	7	0.7
learned new	6	0.6
see world	6	0.6
instructor caring	6	0.6
science diff	6	0.6
prior interest	6	0.6
continue to learn/use	6	0.6
multiple perspectives	5	0.5
sense of belong	5	0.5
inspired	5	0.5
recommend	5	0.5
flexible grading	4	0.4
pictures	4	0.4
critical thinking	3	0.3
curious	3	0.3

confident communicating	2	0.2
video project	2	0.2
cultural fluency	2	0.2

In summary, the voices of interviewees shed light on two main concepts: (1) knowledge acquisition during the class, and (2) ownership of knowledge after the class ended. During the class experience: there were many opportunities to engage, flexible grading that rewarded that engagement, the topics were interesting and relevant. The students in the course with increased cultural relevancy (CR) felt the instructor cared and they developed a sense of belonging. After the class experience there was: a sense of pride in the knowledge gained; greater ability to communicate the ideas, the tendency to continue learning and practice of critical thinking. These skills were highly valued by the interviewees.

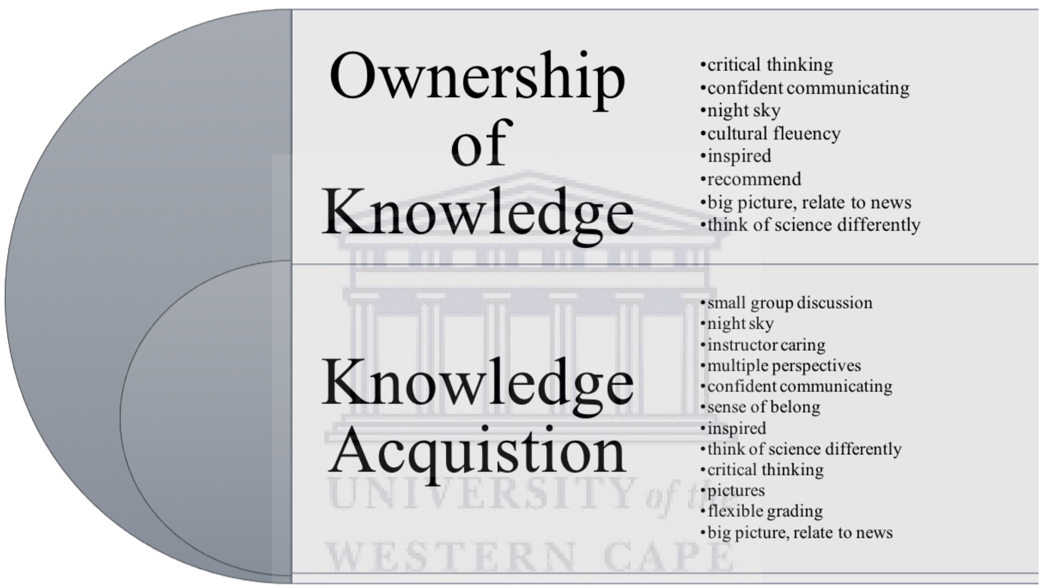


Figure 36 - Conceptual Model of Interview Data, based on 'down-the-pipeline' student interviews, CR (treatment) course

To summarize and relate these insights directly to the key questions addressed in this study:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?* Yes students in the course with increased cultural relevancy (CR) were highly engaged, as indicated by the interview data and analysis. All students interviewed spoke directly to this point. All were in agreement that the course with increased cultural relevancy (CR), or the treatment course, was a very positive experience on many different levels especially compared to other college course they had taken, which had mostly been lecture-based.

- *How does culturally inclusive curriculum qualitatively affect knowledge acquisition for ASTR 101 students?* As indicated by the interview data and analysis, the CR curriculum included topics that were relevant, meaningful, even controversial to the students, such as the night sky or the possibility of alien life. Students overwhelmingly liked small group discussion. They wanted to know what other students were thinking. The course with increased cultural relevancy (CR) gave them the opportunity to discuss multiple perspectives in order to create or evolve their own viewpoints. They needed the CR course structure to build opportunities for communication. This led to an increased sense of belonging and a perception that the instructor cares.

- *Will underrepresented students be positively affected by teaching ASTR 101 with increased cultural relevancy?* Yes, the interview data indicates female students, students of color, international students, and URM students were all positively affected by being in the course with increased cultural relevancy (CR). Several students talked about feeling confident enough to talk about these ideas to their peers after class ended. They owned the knowledge. They were equipped with the tools of critical thinking which gave them confidence. This change was at least in part due to being a part of the culturally responsive (CR) course where discussions involving multiple perspectives happened regularly.

Chapter Six: Discussion

The primary research question guiding this study was:

Will ASTR 101 students, particularly underrepresented groups in STEM, be more engaged and show positive learning gains when culturally inclusive content and culturally responsive instructional strategies are implemented?

In this chapter, implications of the results found in this study are discussed, along with important connections to both the conceptual and the theoretical frameworks within the context of the STEM higher education landscape.

6.1 Learning Gains and Higher Engagement

This study investigated whether students in a course with increased culturally responsive pedagogy, the CR (or treatment) course, would have higher learning gains and experience greater engagement as compared with students in a course taught without increased cultural responsiveness, i.e. using a combination of traditional (T) and interactive engagement (IE) learning methods, referred to as the IE (or control) course. Indeed, it was found that the students in the culturally responsive (CR) course earned higher course grades and higher scores on the post concept inventory, than the students in the IE (control) course, even though the content was comparable in both courses. There was a 48% increase in the number of students who earned an 'A' in the course with increased cultural responsiveness, the CR course, as compared to the IE (control) course, even though the grading was very similar in both courses. There was a 30% increase in the class average normalized gain of the ADT concept inventory in the course with increased cultural responsiveness, the CR course, as compared to the IE (control) course.

The culturally responsive (CR) course improved student learning gains significantly, and did so disproportionately well for underrepresented minority (URM) students. Underrepresented minority (URM) students in the culturally responsive (CR) were *nearly eight times* more likely to earn an 'A' in the course compared to URM students in the IE course. In another measure of disciplinary knowledge, the ADT v2.0 concept inventory, URM students in the CR course earned a 29% average individual normalized gain, which is the *highest gain* as compared to all other groups in the study, including non-URM students. To be clear, this gain for the URM students in the CR course was nearly *three times* higher than for their counterparts in the control course (URM students in the IE course). Recall that the national average gain for the concept inventory (ADT v2.0) is 22% (Deming 2002), and that these profound student learning gains unfolded in a large 'lecture' class of nearly 200 students.

In spite of entering the course with slightly lower overall interest in astronomy, students in the culturally responsive (CR) course experienced greater engagement as measured by the COPUS data and anonymous student survey data. Students in the CR course reported feeling 'less bored', 'more excited', 'more curious', and an 'increased sense of belonging'. Survey data measured significant correlations between engagement and: 'multiple perspectives', 'the night sky', 'learned something new', and 'used pictures'. Students were more likely to recommend a class when the activity included: 'multiple perspectives', 'used pictures', and they felt 'a sense of belonging'.

Interview data conveyed an additional layer of insight into why students experienced greater engagement. Some common themes included: a sense of the ‘instructor caring’, small group ‘discussions’ with ‘multiple perspectives’ on cutting-edge topics, ‘the night sky’, ‘use of pictures’, and a ‘sense of belonging’. The way the course was taught was important to the students. One student summarized their favorite assignment as, “Show me what you know and have fun showing the knowledge”. In addition to the satisfaction of acquiring new knowledge, students shared a sense of ownership and confidence in knowing.

Findings thus far have shown that students, particularly underrepresented groups in STEM, were more engaged and showed positive learning gains when in a culturally responsive (CR) course. In relation to engagement and class-size, the culturally responsive (CR) course had nearly 200 students enrolled in a fixed seating lecture-style auditorium classroom, and yet the small group discussions were robust and meaningful. This is an interesting comparison to the IE (control course) which consisted of 60 students in a fixed seating classroom, with once-a-week lab sections of 20 students each. The results of this study found that a large class size and/or classroom layout were not barriers in implementing successful culturally responsive active learning. These next two sections explore possible mechanisms for these meaningful gains.

6.2 Why Did Students Enrolled in the Culturally Responsive (CR) Course Gain More Content Knowledge Compared with Students in the Interactive Engagement (IE) Course?

This study found that students enrolled in the culturally responsive (CR) course significantly outperformed their peers in the IE (control) course. A key question considered here was: *why* did the students in the culturally responsive (CR) course gain more knowledge compared with students in the IE course?

Using the COPUS observation protocol to create empirically based profiles of both student and instructor behaviors in an introductory astronomy college classroom allowed for finer resolution of the situation. Both the CR (treatment) and the IE (control) courses had traditional lecture classes and active learning classes in similar proportions. Both courses were found to have students talking about 13% of the class-time. The main difference in the COPUS profiles between the two course deliveries was that in the culturally responsive (CR) course the students were working nearly *double* the amount of time as in the control course (16% versus 29%), and the instructor was guiding 13% more time in the CR course compared to the IE (control) course (24% versus 37%).

Clearly, students were learning more by doing more. But what are the underlying pedagogical factors driving the culturally responsive (CR) course towards the more successful results? Evidence found in this study from the student survey data and the student down-the-pipeline interviews gave direct indications to the reasons why increased culturally responsive (CR) learning was more effective. From a wide-ranging perspective two broad-based themes emerged from these data sets: (1) the emotions of learning; and (2) the use of the visual language in learning.

6.2.1 Emotions of Learning

Evidence from the COPUS data and the anonymous student surveys definitively indicated amplified student engagement in the course taught with increased culturally responsive (CR) pedagogy. Further insight into the causes of engagement were found from the survey data and the student interviews. Statistical analysis of the survey data indicated that students enrolled in the culturally responsive (CR) course were: 'less bored' and 'more excited'. In addition, they were slightly 'more curious', felt a greater 'sense of belonging', and were 'engaged'. Furthermore, students in the CR course recommended a class when the class activity used 'multiple perspectives' and 'pictures', and when they felt a 'sense of belonging'.

6.2.1.1 Brain Research

Neuroscience has provided new evidence and insights into teaching and learning. "Learning, as a brain function, is a biological process invented for survival" (Madrazo and Motz 2005, 56). Neuroscience research concludes there are 86 billion neurons in a human brain (Randerson 2012) and each neuron can connect with as many as 10,000 other neurons. Probabilistically speaking there are up to 40 quadrillion total connections in the brain (Ratey 2001). Learning physically changes the make-up of the brain and the functional organization of the brain (Bransford, Brown, and Cocking 2000). When new information is learned, new connections are made, when information is not used, connections fade away (Doyle and Zakrajsek 2013). As the landscape in higher education is rapidly changing, the classroom interactions, strategies, curriculum, and delivery methods must adapt (Zull 2002).

Gerry Madrazo and LaMoine Motz (2005) recommend using positive emotions. "Teaching tied to positive emotional experiences will lead students to generate new thoughts and motivation to learn" (Madrazo and Motz 2005, 57). In the student interviews there was repeated mention of 'having fun while learning' or 'the class was fun' in addition to the survey responses including "excited to learn" and "not bored". Clearly the experience of learning is emotional. Neuroscience research indicates that memory is 'multifaceted and distributed', meaning it is reassembled from many different parts of the brain (Byrnes 2001). And so it follows that memory-dependent learning should engage students in multiple pathways for learning, such as using language and communication skills (Madrazo and Motz 2005). As Hammond argues in the book, "Culturally Responsive Teaching and the Brain" (Hammond 2015), the first step towards culturally responsive teaching is examining cultural bias. "Culture is like the air we breathe, permeating all we do. And the hardest culture to examine is often our own, because it shapes our actions in ways that seem invisible and normal" (Hammond 2015, 55).

Specific activities in the CR course were designed to engage students in a broader conversation, challenge students to dissect their own beliefs, and communicate their beliefs both in writing and orally. One activity called, "What is your connection to the Stars?", started with a series of survey-like questions answered individually on a Likert scale, 'I think there exists a connection between the stars, sun, moon, planets, etc. and humans', or 'I follow a system of astronomy (or astrology) different than the western science view.' Everyone participates. The invitation is compelling. There are no 'wrong answers'. This activity continues with the question: What kind of reasoning supports your point of view? Answer choices are: physical, mental, emotional, spiritual, other; explain. And then a quote from Carl Sagan leads into the final question of the first half of this activity, "Our feeblest contemplations of the Cosmos stir us. There is a tingling in the spine, a catch in the voice, a faint sensation, as if a distant memory, of falling from a great height. We know we are approaching the greatest of mysteries" (Sagan 1980, 4). The question for the student to address was, 'How does it make you feel when you look at the night sky?' All of these answers are from an individual perspective. Part two of the activity poses more questions to be answered as a group such as: 'Has anyone in your group seen the Milky Way?', 'Does anyone notice light pollution at night?', 'Does your group think there will be a generation that has never seen a dark night sky?' and so on. Only after a positive learning experience established the common ground between student and instructor, between student and other students, the more formal, analytical, technical ideas were pursued. In this example, some of the content-based ideas were: scale of the universe, cosmic address, the scientific method, definitions of light year, astronomical unit (AU), planet versus dwarf planet, nucleosynthesis, atomic structure, composition of the human body, chemical abundance models of the Solar System, evidence of the Big Bang, and the large scale structure of the Universe. New information is connected to old information (past experience), new neural connections are forged. The results of this study show that a more positive learning experience, one that is more inclusive of the whole human (mind, body, heart, and spirit), more inclusive of diverse viewpoints, compelling with opened-ended discussions, led to increased engagement and higher learning gains.

6.2.1.2 Sense of Belonging

Work from the disciplines of psychology and anthropology have made it clearer that learning that takes place in a group setting influences learning in a powerful way (Bransford, Brown, and Cocking 2000). Another aspect of the emotional or psychological part of learning comes from a growing body of research on 'sense of belonging'. Simply put, this is a human emotional need to be part of the group. From the evolutionary perspective, there is a deep-rooted need for the group in order to enhance chances of survival. Indigenous communities continue to acknowledge this high priority of group collaboration, for example, in tribal membership. Since all humans beings were once part of some cultural community, it can be argued that most people still have a human desire to be part of the group, to belong (Baumeister and Leary 1995; Fiske 2018).

In this study it was found that sense of belonging was significant in both the survey results and the interview data analysis. In the anonymous student after class surveys, a class was more likely to be recommended when the student felt they belonged. In the interviews a sense of belonging was mentioned in accord with the frequent use of small group discussions.

> *I liked 'Talk to your Neighbor'… it kind of made it have a sense of belonging…like you actually felt belonged because you were talking...If you didn't say we had to have a conversation with your neighbor. I wouldn't. We would help each other, so yeah that made me feel belonged.* (Interviewee from the CR course)

Roy Baumeister and Mark Leary, two psychology researchers, published "The Need to Belong: Desire for Interpersonal Attachments as a Fundamental Human Motivation" (1995). This widely cited article assembled a large amount of empirical evidence to investigate how well the belongingness hypothesis (that people have a pervasive drive to form and maintain positive and meaningful personal relationships) fits the data. Results found that belongingness had "multiple and strong effects on emotional patterns and on cognitive processes" (Baumeister and Leary

1995,497). And that "Lack of attachments is linked to a variety of ill effect on heath, adjustment, and well-being" (Baumeister and Leary 1995, 497). This concept of belonging was also studied in mental health settings (i.e. psychiatric nurse practice) and found to be relevant and important in clinical use (Hagerty et al. 1992; Hagerty and Patusky 1995; Hagerty et al. 1996). Around the same time, Sylvia Hurtado et al. applied this concept of belonging from social psychology to address campus racial climates and low retention rates for Latino undergraduates (Hurtado and Carter 1997). Other scholars in post-secondary education continued to find important results based on qualitative and quantitative investigations of sense of belonging (Hoffman et al. 2002; Juvonen 2006; Freeman, Anderman, and Jensen 2007; Strayhorn 2018). In a 2007 study involving college freshman at Midwest universities published by Freeman et. al. it was shown that students' academic self-efficacy, intrinsic motivation, and task value were all closely associated with a sense of belonging (Freeman, Anderman, and Jensen 2007). In 2013 the connection between student attrition rates in the U.S. was linked to sense of belonging (O'Keeffe 2013). More specifically, the 30-50% student attrition rate in the U.S. was correlated to: lost revenue for higher education institutions, misappropriation of government funds, and a weaker labor market. Students at highest risk are: first year, part-time, and first generation students (O'Keeffe 2013). Patricia Graham et. al. suggested a 'persistence framework' that views confidence and motivation as a cyclical process, suggesting three key interventions in STEM: early research experiences, active learning, and learning communities (Graham et al. 2013). Consistent with the broader educational research, the human drive to feel a 'sense of belonging' was identified to be of paramount importance in supporting learning gains and increased engagement in this study.

6.2.2 Visual Language

Statistically significant correlations with engagement and course satisfaction were found to be 'use of pictures' and the 'night sky'. In addition to the survey data, the interview analysis reiterated these points: personal connection with the night sky and fascination with the pictures (mentioned by several students as 'nebulas').

6.2.2.1 Night Sky

Ninety percent of the students interviewed expressed a deep appreciation of learning about the night sky, for example, "I will never look at the night sky the same again…I'm outside and …I recognize that" (Interviewee from the CR course). Another student commented, "I've always been intrigued by stars and I always would stare at the night sky when I was younger and I was like it's time to just know about it…" (Interviewee from the CR course). And "…it kind of makes me want to go into the field [astronomy]…I find myself looking up at the stars a lot more than I used to …it's so interesting" (Interviewee from the CR course).

As long as humanity has existed, every culture, every place in the world, there has been a connection to sky.

> *There is no human society that does not somehow, in some way, relate its fears, concerns, hopes, and wishes to the sky, and to the organizing principle behind it, the cosmos. Neither is there any society that does not express at least some fascination with the sky and its mysteries. This is as true of modern culture as of ancient culture.* (Campion 2012, 1)

Hamacher and Norris have pointed out that "For more than 50,000 years, Indigenous Australians have incorporated celestial events into their oral traditions and used the motions of celestial bodies for navigation, time-keeping, food economics, and social structure" (Hamacher and Norris 2011,1). Indigenous astronomy and cultural astronomy are gaining momentum and greater recognition as interdisciplinary academic disciplines (Ruggles 2010) through projects such as: "The African Cultural Astronomy Project" (Urama and Holbrook 2009) and First Nations revitalization efforts (Lee 2016; Buck 2018; 2012; Maryboy and Begay 2005; Bryan 1955; Lee 2013).

And yet, in 2004 Zeilik and Vicky Morris-Dueer surveyed two different samples of college level introductory astronomy instructors in a study designed to find the highest priority concepts that should be taught in ASTR 101 (Zeilik and Morris-Dueer 2004). The results found that the electromagnetic spectrum and mass were top rated among the two groups. Of the 200 potentially essential topics on the survey 'constellations' was ranked 144th in importance, or in the lowest 28%. Similarly, in a 'most frequent ASTR 101 topics' study by Slater 2001 'naked-eye astronomy' was ranked 11th out of 13, again near the bottom of the list (constellations were not included as a topic) (Slater et al. 2001). However, the results of this study clearly showed that the 'night sky' was an essential topic in the ASTR 101 course taught with increased cultural responsiveness (CR). It is worth noting that in anonymous student surveys in the IE (control) course, learning about the 'night sky' was highly rated, in spite being taught only minimally and with a technical emphasis in accordance with the textbook, (i.e. one chapter or one lecture). In the CR course, the night sky was used as a bridge of common ground between student and instructor, between astronomical concepts and human curiosity, between past experience and future practice. A fertile ground was found where curiosity and excitement were already seeded from the student's experience outside of the formal classroom, a place where new ideas were welcomed and led directly into a more complex quantitative analysis. Each quarter of the class, a new "Current Night Sky Map" was used as a framework for learning that served as a bridge between constellations, astronomical treasures, new research, and unanswered questions in science and astronomy. See Appendix E-Sample Curriculum.

Figure 37- 'Current Night Sky-Fall and Summer Stars', Lee, 2018

Figure 38-'What's the Big Idea-Do You Believe', Lee, 2018

6.2.2.2 Astronomical Images

In addition to the visually-based learning of the night sky, a photo gallery called "What's the Big Idea?", containing color reproductions of iconic astronomical images served as a compelling platform for visually inspired narrative-based pedagogy. For example, in Part 2 of the course the focus was "Are We Alone?". The star map contained the seasonal stars and constellations best seen in the Summer and Fall. The photo gallery contained images such as: the Kepler Space Telescope, SgrA*, M13 globular cluster, Arecibo message, Voyager Golden record, Andromeda galaxy, Titan, the Pleiades, Fomalhaut b, and space bears (see Appendix E-Sample Curriculum-Part 2). These images, many of which were taken with the Hubble Space Telescope, tell the incredible stories that are related to the constellations of seasonal focus. The iconic images are embedded with aesthetic beauty as well as scientific meaning. Like the star maps, the use of the images allowed for a place of common ground, a bridge between instructor and students that acted like a springboard into the more formal astronomical ideas. The author of this study recognizes that there is a balance here between aesthetics and rigor, and then the mathematics adds another layer of intrigue to the story.

Appreciation of the repeated and frequent use of the visual imagery imbedded in multiple layers of story was clearly seen in the student interviews: "The pictures were super cool…super vibrant colorful pictures…it just draws your attention…it's not just like black with stars….", said one interviewee. Another added, "Nebulas…they're fascinating to me…the colors is partly the reason why I am fascinated…It's strange and different". Followed by, "(the course) was really interesting...It really attracts your attention because you have a lot of visuals…" (Interviewees from the CR course). The use of powerful astronomical images that convey story is a tool rooted in culturally responsive pedagogy (CRP) as clearly detailed by Gay:

> *Stories … are powerful means for people to establish bridges across other factors that separate them (such as race, culture, gender, and social class), penetrate barriers to understanding, and create feelings of kindredness….stories educate us about ourselves and others; they capture our attention on a very personal level and entice us…* (Gay 2010, 2-3)

Powerful visual images allow students to be attracted to and to remember the stories contained within the artistry. As participants of the 21st century, students are well versed in communicating within a visual culture. As science educators, and science communicators these images are one of the corner-stones of learning astronomy, a powerful tool for communication, not simply a decorative add-on (Rodríguez Estrada and Davis 2015).

6.2.2.3 Visual-Spatial Ability

In 1983 the education researcher, Howard Gardner, argued that psychologists have been narrowly and mistakenly focused on only two types of intelligence: linguistic-verbal (reading and writing), and logical-mathematical (calculations and quantification). He proposed a theory of multiple intelligence (MI), asserting that in addition to these two cognitive skill sets there are another six domains of intelligence: visual-spatial, bodily-kinesthetic, musical-rhythmic, interpersonal, intrapersonal, and naturalistic (Gardner 1983). He later revised the multiple intelligence (MI) list to contain seven domains: logical-mathematical, linguistic, musical, spatial, bodily-kinesthetic, interpersonal, and intrapersonal (Gardner and Hatch 1989). In either case, Gardner et al. have argued that all human beings are capable of these relatively independent forms of intelligence, and that assessment should be broader, with the goal of using the broader spectrum of intelligences as a basis for engagement and learning (Gardner and Hatch 1989; Tanner and Allen 2004; Trumbo 1999; 2000; Christopherson 1997). Researchers like Felice Frankel et al. have urged the use of data visualization and animation in science as well as collaboration across disciplines to improve student performance and motivation in STEM fields (Frankel and Reid 2008; Borner 2012; De Leo–Winkler, Canalizo, and Wilson 2016; McGrath and Brown 2005; McGinn and Roth 1999). Frankel argues that these approaches would have a two-fold effect: firstly, "advancing their (the students') understanding of science", and secondly that "students who would not ordinarily consider science as part of their educational experience might, in fact, become drawn to science as they see and use the more welcoming and accessible tools of the visual language" (Frankel 2005, 158).

In a 2005 national report, "Learning to Think Spatially", the committee concluded that "spatial thinking is pervasive: it is vital across a wide range of domains of practical and scientific knowledge; yet it is underrecognized, undervalued, underappreciated, and therefore, underinstructed" (National Research Council 2005, 14-15). The reports goes on, "The process of moving from the human wonder at the glory of the night sky to a scientific understanding of the structure and evolution of the universe is a remarkable story, made possible to a significant degree by insights and inferences generated by spatial thinkers" (National Research Council 2005, 56). Since then an overwhelming amount of studies have shown empirically a strong connection between successful STEM students and spatial thinking (Wai, Lubinski, and Benbow 2009; Newcombe 2010). It is interesting to note that Einstein himself wrote in a letter to an associate, "The words of the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined" (Einstein 1954). In 2014, Lori Andersen published an article reiterating that quantitative and verbal reasoning skills have dominated in education, and that many students that have high spatial abilities, but lower math and verbal abilities are being left out of STEM at an early age, eventually leading to underemployment or unemployment (Andersen 2014).

The results of this study strongly show that the prominent use of the visual language coupled with narrative pedagogy, specifically in regard to the night sky and astronomical images, is yet another reason why the students in the (CR) culturally responsive course were more likely to succeed both in acquiring science content knowledge and in the experience of learning. As suggested by the results of this study and the literature presented above, there is an untapped potential here.

6.3 How Were Underrepresented Minority (URM) Students Positively Affected by Participating in the Culturally Responsive (CR) course?

Positive learning gains coupled with increased engagement identified for students in the culturally responsive (CR) course is undeniable. Additionally, an important element of this second-generation study was to gain a more nuanced understanding of the effect of increased relevancy for underrepresented minority (URM) students. *Why did URM students in the culturally responsive (CR) course outscore all other students in the study?* Based on the concept inventory, normalized individual learning gains for the URM students in the CR course were 29.4. The next highest gain was 28.6 for the non-URM students in the CR course. Normalized individual gain for the URM students in the IE (control) class was 10.6. Comparing only the URM student gains between the CR (treatment) course and the IE (control) class reveals an increased gain of 177% for URM students in the culturally *responsive* (CR) course (29.4 CR course versus 10.6 IE course). Underrepresented minority (URM) students in the CR course on average earned *one letter grade higher* than URM students in the IE course (81.5% = 'B' CR course versus 76.9% = 'C' IE course). Additionally, underrepresented minority (URM) students in the culturally *responsive* (CR) course were nearly *eight times* more likely to earn an 'A' than URM students in the IE course (47.2% CR course versus 6.3% IE course).

In education research, there is increasing evidence that active learning improves URM student performance. Haak et al. (2011) published a study of college-level introductory biology students where the intervention consisted of 'increased course structure'. Instead of underrepresented minority (URM) status, the Haak et. al. study collected data from students enrolled in the university's Educational Opportunity Program (EOP) which typically serves low-income and first generation students, and where approximately 77% of URM students are also EOP students. Upon comparison of the course with increased structure to the control course with little or no active learning, it was found that "although all students benefit from structure, EOP students experience a disproportionate benefit" (Haak et al. 2011, 1215) in the highly structured course. It was suggested that highly structured course format could potentially reduce the achievement gap, while benefiting all students, and without additional funding commitments. Similarly, Eddy and Hogan showed in a 'moderately structured' introductory biology course, that all students in the intervention course benefited but again the Black students and first generation students benefited disproportionately (Eddy and Hogan 2014). Eddy and Hogan found evidence of three main factors that impacted the learners: time allocation-students in the intervention course spent nearly double the time per week and were twice as likely to attend class; classroom culture-the moderate structure of the intervention course led to more of a community environment instead of a competitive environment; and course value- surprisingly, student in both courses valued the class equally (Eddy and Hogan 2014). Increased course structure is defined by Haak: "daily and weekly practice with problem solving, data analysis and other higher-order cognitive skills" (Haak et al. 2011, 1213) and "exercises that challenge previous conceptions and require students to explain their thinking" (Haak et al. 2011, 1216). Eddy and Hogan described a moderately structured as: "graded preparatory assignments, extensive student in-class engagement, and graded review assignments" (Eddy and Hogan 2014, 455). The findings in this study are certainly in agreement that increased course structure is a mechanism for increasing student performance, and yet the interview and survey data suggest broader, more holistic factors as well.

Evidence from the anonymous student surveys and the student interviews in this study revealed two critical themes that are particularly relevant to URM students: the inclusion of 'multiple perspectives', and the importance of 'relationships' in the learning experience. As Ladson-Billings pointed out in 1994, culturally relevant pedagogy, "empowers students intellectually, socially, emotionally, and politically by using the cultural referents to impart knowledge, skills, and attitudes" (Ladson-Billings 1994). She goes on to say, "These cultural referents are not merely vehicles for bridging or explaining the dominant culture; they are aspects of the curriculum in their own right" (Ladson-Billings 1994, 20). In other words, adding contributions of women or people of color, into a traditional lecture is only a very small first step. True culturally responsive pedagogy (CRP) infiltrates the learning environment continually. Gay (2010) specifically points out eight *'character profiles'* of culturally responsive teaching:

validating, comprehensive, multidimensional, empowering, transformative, emancipatory, humanistic, and normative (Gay 2010, 36-46). Note that this was previously cited in Section 3.2.1 on page 48 of this paper. The fact that students in this study singled out, inclusion of 'multiple perspectives' and importance of 'relationships' as directly contributing to their engagement and class satisfaction clarifies these factors not only as successful teaching methods but also deeply rooted in culturally responsive pedagogy (CRP).

6.3.1 Multiple Perspectives

Specifically Gay (2010) points out that what is considered "cultureless mainstream U.S. schooling" is really "Eurocentric culturally responsive education" (Gay 2010, 45). The default culture in the U.S. is the Western European culture which is a direct biproduct of colonialism (Johnson and Murton 2007). Transforming a course to become a culturally responsive course requires the spectrum of teaching and learning to include both different ethnic perspectives and different societal points of view.

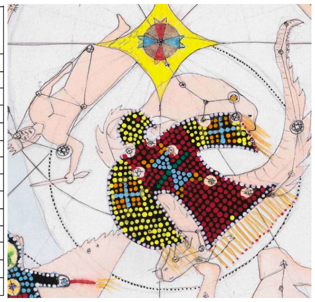
In 1987, a three-year study was done to examine higher education by the Carnegie Foundation for the Advancement of Teaching. The Carnegie Report stated:

> *…we propose an approach to general education we call the 'integrated core'… we mean not a rigid set of courses but a thematic approach …that concerns itself with the human experiences that are common to all people. The goal, we say, is to broaden the perspective of the students and help them connect the disciplines to the human condition.* (Boyer 1987, 15)

6.3.1.1 Ethnicity/Race

How did the culturally responsive (CR) course include different ethnic perspectives? One example of inclusion of culturally responsive pedagogy was seen in the curriculum. Within the context of an introductory astronomy course it makes sense to point out non-Western European constellations along with the 'Greek' constellations, which then leads into a conversation about how many different cultures have a connection to the stars and cosmos. For example, one common topic well-known to the northern hemisphere observers is the bright asterism, the Big Dipper. This group of seven bright stars is known as 'To Win/Tun Win' (Blue/Birth Woman) in D/Lakota (Lee 2016), 'Ojiig' (Fisher) in Ojibwe (Lee 2013), the Indigenous peoples of land now called Minnesota (Mnisota Makoce). The Chinese associated these stars with the throne of the god of literature (Needham and Ronan 1985). The Egyptians saw the bull's leg and associated the shape with the sacred tool (adze) used in the Opening of the Mouth ceremony (Krupp 1983). In addition to simply including non-Western constellations, more complex ideas based on Indigenous astronomy were incorporated into the CR course. For instance, the topic of precession was presented as directly related to the D/Lakota Thunderbird 'Wakinyan' constellation that resides at the center of the 26,000 year wobble circle of Earth's rotational axis (Lee 2016). This particular example, "The Motion of the North Star and the Thunderbird", included a lab-like learning activity where students first collected data (using planetarium software), found patterns, and then made predictions. See Appendix E-Sample Curriculum. The pertinent question here after all the scientific knowledge has been comprehended is: how did the Indigenous people of the D/Lakota tribe know about precession?

	Years from present:	Year:	NCP position: RA	NCP position: Dec.	Notes	Indicated on Star Map
1.	0	2000 AD	0h	90°	in Ursa Minor, very near Polaris	☑
2.	2000	4000 AD	23h 5m	79° 0'	in Cepheus	☐
3.	4000	6000 AD	22h 18m	68° 44'	in Cepheus	☐
4.	6000	8000 AD	21h 24m	59° 25'	in Cepheus	☐
5.	8000	10,000 AD	20h 28m	51° 36'	in Cygnus	☐
6.	10,000	12,000 AD	19h 30m	46° 21'	in Cygnus	☐
7.	12,000	14,000 AD	18h 30m	43° 30'	in Lyra	☐
8.	14,000	16,000 AD	17h 30 m	43° 25'	in Hercules, near the bright star Vega	☐
9.	16,000	18,000 AD	16h 30 m	46° 22'	in Hercules	☐
10.	18,000	20,000 AD	15h 32m	51° 46'	in Draco	☐
11.	20,000	22,000 AD			in Draco	☐
12.	22,000	24,000 AD			in Draco	☐
13.	24,000	26,000 AD			in Ursa Minor	☐
14.	26,000=0	28,000AD= 2000 AD			in Ursa Minor	☐



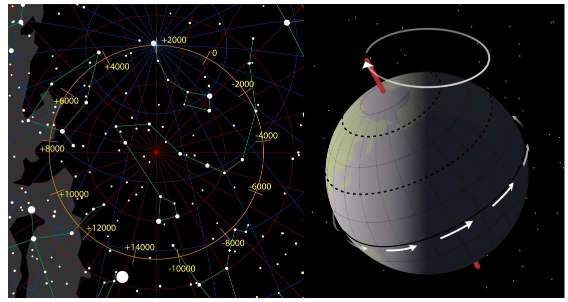


Figure 39 - (on left) "Motion of the North Star" (Lee 2016) *(on right) Scientific figures ("Precession" 2008)*

Other lab-like learning activities were presented such as: "The Motion of Venus", with Maya (Aveni 1997) and Ojibwe connections (Lee et al. 2012), and "Dark Sky Constellations", which included cosmologies of the Aboriginal Australians (Gullberg et al. 2019) and Dine-Navajo (Maryboy and Begay 2005), both representing Indigenous cultures across two hemispheres. Connections can be forged with the cultural knowledge and stories that mirror the movement of the celestial bodies in the sky with the animal, people, or mythological figures on Earth. For example, the Ojibwe view the Big Dipper as the Ojiig-Fisher. In addition to the important cultural teachings, the behavior of the fisher is known to be ferocious, neither nocturnal or diurnal but always on the go, frequently circling its prey in battle. This is same pattern of motion as seen by the movement of the Big Dipper from the ground, circumpolar motion. This dual perspective is exactly 'two-eyed seeing' (Bartlett, Marshall, and Marshall 2012, 336).

Even when a course has the racial makeup of mostly majority students, as was the case in this study (80% majority students), there is still a need for all students to learn 'cultural agility' (Caligiuri 2012). This is especially true in this time of global connectedness (via the internet) and light of the diversity explosion in the U.S. (Frey 2018). Explained nearly a decade ago, "A benefit for all students across ethnic, racial, and social groups is acquiring deeper and more accurate knowledge about the cultures, lives, experiences, and accomplishments of diverse peoples in U.S. society and humankind" (Gay 2010, 44). In numerous recent studies employers were asked about the skill set of their potential new hires, college graduates. Employers ranked 'global/intercultural fluency' as one of a handful of essential skills that are not being adequately taught at the college level (Eckes 2019; Gercar 2019; Welikala and Watkins 2008; Scott 2010; Mourey, Lam, and Oyserman 2015).

6.3.1.2 Science and Society

How did the CR course include different societal perspectives? Throughout the culturally responsive (CR) course small group discussions were used to address larger questions that were relevant to astronomy, space, and science in general. Students were asked to answer open-ended questions, then use critical thinking skills to delve into why they think what they think. Topics included: 'What is your connection to the stars?', 'Do you believe in extraterrestrial life?', 'Would you go on a one-way mission to Mars?', and 'Would you go through a worm hole and meet your other self?'. Other activities, allowed students to work in groups with designated team members (moderator, scribe, skeptic, proposer) (Bennett and Shostak 2007), to practice verbal and written communication skills while addressing a larger issue: 'Your team has been assigned to create an international plan for first contact with alien life, what are the top five action items listed in priority?', 'What does your team think of the lunar tourism #dearMoon project…do you think it will inspire peace to bring artists to the Moon?', and 'A person claims to be from a parallel universe. Your team must design a way to test this person's claim and determine if they are really from another universe'. And some group discussions were generated online after reading or investigating a topic such as: 'Are robots taking over the jobs?', 'Will light pollution cause the end of night?', 'What political, economic, or cultural factors might influence the use of light at night for someone different than yourself?', 'Would your life be any different without science?', 'Suppose there is an alien planet, that has life on it. Do you think that colonization is inevitable? Or is this a 'uniquely human' characteristic?' (see Appendix E-Sample Curriculum).

Both Ladson-Billings in defining 'culturally relevant pedagogy' and Gay defining 'culturally responsive pedagogy' speak to the relationship between classroom discipline-based knowledge and bigger-picture real world applications of knowledge and knowing. Ladson-Billings writes in 1994 in her landmark book, "The Dreamkeepers: Successful Teachers of African American children":

> *I went into the classrooms intending to examine both 'the political and the practical'. I wanted to see not only why a certain kind of teaching helped the students to be more successful academically but also how this kind of teaching supported and encouraged students to use their prior knowledge to make sense of the world and to work toward improving it.* (Ladson-Billings 1994, 15)

According to Gay (2010) the first descriptor of culturally responsive teaching (CRT) is: 'validating'. CRT "can be defined as using the cultural knowledge, prior experience, frames of reference…to make learning encounters more relevant to and effective for them…" (Gay 2010, 36). In the second character profile of CRT Gay goes on to describe 'inclusivity. "Students are held accountable for one another's learning as well as their own", (Gay 2010, 38). A key premise of culturally responsive teaching (CRT) is that students "develop a sense of community, camaraderie, and shared responsibility" (Gay 2010, 38). Allowing the emotions, beliefs, opinions and feelings to exist alongside the factual information in the classroom, acknowledges the student's life experience outside of the class and their existence as a whole person. This speaks to the third descriptor of CRT, which is 'multidimensionality'. It follows that the student then feels empowered as a learner and a greater sense of personal confidence, which is Gay's fourth tenant, culturally responsive teaching is 'empowering' (Gay 2010, 40).

Indeed these sentiments were clearly echoed in the student interviews. From the students' perspective, the broader view of science in society was a definite source of engagement. Statements were:

> *I just realized that it's kind of like…a broad spectrum. There's a lot to learn. I always thought of science as being like chemistry and like that kind of stuff. But it's not, it's actually...a lot of fun. I've always wanted to take like science classes and math classes..*
>
> *I just thought like well my life would be totally different without science…I didn't know anything about gene editing about any of all that so that was really interesting to learn about and I just didn't know it existed.*
>
> *I remember…you mentioned a question something about like you know if you were able to go to Mars and live there…Some of this ethical stuff I like tying that*

> *stuff into it because I feel like there's more to astronomy than just you know that one piece of learning how the math and stuff works too... you know... equations.*
>
> *You are applying it to the news like this is what's happening like with the planets that might potentially have life … That's why I remember the concept. That's why it makes it more meaningful and useful.*
>
> (Interviewees from the CR course)

6.3.2 Relationships

While examining insights into how underrepresented minority (URM) students were effected by participating in the course with increased culturally responsive (CR) instruction, *relationships* were found to be an essential component of student success. Recall that URM students in the culturally responsive (CR) course outscored all the other students in the study including male and female majority students (based on concept inventory learning gains). This exemplifies a huge gain. Two key themes were looked at more in depth: effect of 'sense of belonging on URM students' and student's perception of the 'instructor caring'.

6.3.2.1 Sense of Belonging and URM Students

Researchers in the 1990s such as Tinto published results that linked degree attainment and persistence in higher education with a student's ability to connect with peers and faculty (Tinto 1987; Austin 1993). Two major reasons for dropping out of college are failure to establish a social network of friends and classmates and failure to become academically involved in classes (Tinto 1987). "Isolation and alienation are the best predictors of failure" (Smith, Douglas, and Cox 2009, 29-30). Tinto in a keynote speech in 1999 outlined four institutional actions to increase retention: provide clear and consistent degree maps; provide academic, social, and personal support; involve students as valued members of the community; and most importantly students need to learn something "Students who learn are students who stay…Active involvement seems to be the key." (Tinto 1999, 6). Indeed, on the anonymous student survey, in both the treatment course and the control course, this question, 'I learned something new'*,* scored remarkably high (7.92 CR versus 7.84 control). This was well above the average ratings across all survey questions of 7.16 and 6.92 respectively of out 10 points total.

Following Tinto's theory other research had been published to show that mainstream activities as recommended by Tinto might not be as effective for students of color (Johnson et al. 2007). Hurtado and Carter (1997) found that for Latino students a 'sense of belonging' was more appropriate as defined by, "the extent to which individuals feel included in the college community" (Hurtado and Carter 1997, 328). Their research found that a key influence related to sense of belonging was a student's perception of a supportive campus racial climate (Hurtado and Carter 1997). A 2007 study published by Dawn Johnson et. al. broadened these results to find three main factors that correlated to sense of belonging for first year students of color (as defined as African American, Asian American, and Hispanic/Latino students): (1) residence hall climate; (2) transition to college; and (3) overall campus racial climate (Johnson et al. 2007). These findings differ from Tinto in that Johnson et. al, similar to Hurtado and Carter, recommended that institutions pay more attention to both the formal and informal learning environments, which emphasizes more of a shared responsibility between students and institutions.

In a qualitative study by LeVar Charleston et al. (2014) researchers specifically applied culturally responsive pedagogy (CRP) in a computer science course and found that for African American students "social construction trumps academic outlook" (Charleston, Charleston, and Jackson 2014, 412), meaning that positive social influences including a sense of belonging was a greater factor in persistence of the computer science degree than academic ability. Results from this study strongly suggest that increased cultural relevancy in the form of more instructor interaction with students, more students working and discussing in small groups, in spite of being in an auditorium with nearly 200 students, coupled with culturally responsive curriculum and strategies, allowed underrepresented minority (URM) students to excel in both learning gains and engagement.

The findings of the present study, particularly the data from the student interviews, speak to how much success, (from the student's perspective), depended on factors that were wider than text-book facts and more chaotic than algebraic problem solving. The value added in the classroom community was a social and cultural experience. In the ideal, most memorable case, student learning was constructed from their experiences before class, was challenged during class, and had value after the class ended. Studies by Jennifer Case and Delia Marshall with engineering students have shown that disciplinary knowledge is not the only attribute that graduates need to be successful. In fact interviews with Indigenous students working as professional engineers showed that "knowledge matters, but so does the development of individual capabilities, and it is the engagement with knowledge that is central to the development of capabilities in the graduate professional" (Case and Marshall 2016, 17). A 2010 study by discipline-based education researchers (DBER) in physics and chemistry used narrative analysis of senior engineering student interviews to gain insights on their STEM experience (Marshall and Case 2010). A rigorous socio-cultural analysis found that identity constructivism played a key role in student success. Successful students carried an "ownership of their narrative" (Marshall and Case 2010, 494). Personal growth, resilience, and leadership skills of students from disadvantaged backgrounds were excellent coping skills that were in fact an unrecognized advantage in the higher education landscape (Marshall and Case 2010). Results indicated that in addition to disciplinary knowledge a space for personal development or 'student agency' was a critical factor in 21st century STEM higher education (Case and Marshall 2016).

In a related study by Keonya Booker (2016) African-American women undergraduate students were interviewed to gain insight on the importance of relationships with faculty members and peers. The research question was, how do these interactions affect the students' sense of belonging and persistence (Booker 2016). Booker's study found that the African-American female undergraduate students were strongly motivated to finish the degree by relationships with the faculty and their peers. Although the students in this study were not necessarily STEM students, the finding clearly show that:

> *When students share a sense of psychological membership with classmates and instructors, they are willing to take risks and challenge themselves with a greater focus on intrinsic and mastery goal achievement…the reward for such behavior is greater confidence in one's ability, higher academic performance, and positive peer relationships.* (Booker 2016, 219)

This sentiment was echoed in the interviews with the students from the CR course. In particular students of color, (URM plus Asian), in the CR course felt a high level of belonging when they had a positive experience with the instructor and their peers, when content contained real-world examples with multiple perspectives, when their self-esteem was reinforced; they felt engaged and participated more fully.

6.3.2.2 Perception of the Instructor Caring

An interesting result that emerged from the interview analysis of students in the CR class is the idea of the student's perception of the 'instructor caring'. An article published by psychology researcher Elizabeth Canning et al. sheds light on this notion (2019). A longitudinal study of more than 15,000 students, over 600 STEM courses, and 150 STEM faculty at a research university in the Midwestern U.S. found that 'faculty mindset' was the greatest predictor of student performance, (defined as both learning gains and motivation), more than another other single demographic (race/ethnicity, age, gender, etc.) (Canning et al. 2019). Furthermore the study found that the racial achievement gap was *twice* as large for students in courses taught by faculty with a 'fixed mindset' (Canning et al. 2019). Note that the mindset beliefs were self-reported by the STEM faculty members and there were over 1600 URM students in the study.

> *Professor's beliefs about the nature of intelligence are likely to shape the way they structure their courses, how they communicate with students, and how they encourage (or discourage) students' persistence…we argue that faculty beliefs about which students 'have' the ability in STEM might constitute a greater barrier for URM students because fixed mindset beliefs may make group ability stereotypes salient, creating a context of stereotype threat.* (Canning et al. 2019, 4)

The concept of fixed mindset was introduced by Carol Dweck's landmark book, "Mindset: The New Psychology of Success" (2006). Here she proposed that people's beliefs about ability exist on a scale from a 'fixed mindset' to a 'growth mindset' (Dweck 2006). This is particularly relevant for the classroom. A 'fixed mindset' teacher believes the student has only limited abilities. A 'growth mindset' teacher believes failure is an opportunity, and ability can be improved by effort, new strategies, and input from others (Dweck 2015; 2016). Empirical studies clearly show a link between growth mindset and academic motivation (Grant and Dweck 2003; Dweck and Master 2008). In other words, anyone can get smarter if they work at it.

In a 2018 study by Cavanagh et al. students in an undergraduate anatomy course with active learning were surveyed regarding motivation and trust in the instructor. 'Trust' was defined as the student's perception of the instructors: understanding, acceptance, and care. Their hypothesis was that both a growth mindset and the relatively new concept of 'trust' would positively correlate with student commitment to active learning (Cavanagh et al. 2018). Results found that although both trust and growth mindset were significantly associated with commitment to active learning, the level of trust was "the strongest and most consistent predictor of student commitment, engagement, and course performance" (Cavanagh et al. 2018, 5). Growing evidence supports the role of the instructor-student relationship as key in the learning environment (Bettinger and Long 2005; Klassen et al. 2010; Dee 2005; Cavanagh et al. 2018).

Of profound significance, results in this study found female underrepresented minority (URM) students in the culturally responsive (CR) course performed exceptionally well on overall course grade. Looking at the numbers, female URM students in the CR course received *one letter grade higher* (or nearly 10 percentage points) than female URM students in the IE (control) course (83.6% CR versus 74.6 control). In addition, female students of color in the culturally responsive (CR) course that were interviewed specifically mentioned feeling more confident: "I've always been good at science but I've never been confident enough to talk about it and now after this class…I know for a fact that I could say something and it'd be correct…I just feel more confident when I talk about things…" (Interviewee from the CR course). The question worth asking is: How did female URM students in the culturally responsive (CR) course achieve such academic excellence?

Recall that when Ladson-Billings first defined culturally relevant pedagogy in the 1990s her results were based on scrutinizing the teaching ideology and common behaviors of teachers of African-American students between the 1988-1990 school years. The very first tenant of culturally relevant pedagogy was found to be high academic achievement. Ladson-Billing states:

> *While much has been written about the need to improve the self-esteem of African-American students, at base students must demonstrate academic competence…All of the teachers demanded, reinforced, and produced academic excellence in their students. Thus, culturally relevant teaching requires that teachers attend to the students' academic needs, not merely make them 'feel good'. The trick of culturally relevant teaching is to get students to 'choose' academic excellence.* (Ladson-Billings 1995, 160)

The results of this study clearly show the increased learning gains, both academically and personally, as brought about by culturally responsive teaching combined with active learning in the post-secondary STEM classroom.

A relevant publication relating to gender and ethnicity in STEM learning, was carried out by Ralph Preszler. The intervention compared a 3-hour lecture-based course with the same course taught with 2-hours of lecture plus 1-hour of peer led workshops in an introductory biology course (Preszler 2009). Preszler's change in course format found greater learning gains for all students, with additional gains for URM and female students. To explain this, Preszler cites earlier work done by Seymour and Hewitt (1977) where after interviewing students that left STEM, they concluded that for female students developing a personal dialog with the instructor established increased motivation and that this was not as important for the male students. Preszler concluded that this may have been a reason that contributed to female students excelling in the peer-led course structure. This is relevant to the research finding in this study because females students and URM female students excelled in the course with increased culturally responsive methods where personal dialogs were woven throughout.

Gay directly addresses the balance of caring and academic achievement, "Genuinely caring teachers are 'warm demanding' academic taskmasters. All students are held accountable for high academic efforts and performance (Gay 2010, 86). She emphasizes, "The success of these teachers demonstrates that the idea of caring as essential to instructional effectiveness is not merely a truism; it is a fact" (Gay 2010, 86). As demonstrated in this study, significant gains in student performance were critically tied to both the mental and emotional state of being of the students in the culturally responsive classroom.

To conclude, the results of this study showed that students in the culturally responsive (CR) course felt an increased 'sense of belonging'. By the way the course was taught, students perceived that the 'instructor cared'. In addition to the satisfaction of acquiring new knowledge, students shared a sense of ownership and confidence in knowing that was reflected by excellence in academic achievement. The design and delivery of the culturally responsive (CR) course was intentional, increased culturally responsive (CR) pedagogy. From the students' perspective this meant: inclusion of 'multiple perspectives', related to the 'night sky', 'learned something new', and 'used pictures'. Small group discussions were a major tool for creating positive relationships that served as a foundational element of the culturally responsive (CR) course. Effectiveness of the culturally responsive course depended on the instructor identifying elements of cultural value to the students' identity and then weaving them carefully into the discipline-based content and pedagogy where a vibrant classroom community was created awash in culturally responsive active learning.

6.4 Summary of Links Between Culturally Responsive (CR) Course, Culturally Responsive Pedagogy (CRP) and Indigenous Knowledge Systems (IKS)

The purpose of this section is to summarize how the content and approach contained in the treatment course was in alignment with culturally responsive pedagogy (CRP). In addition, this section will show how Indigenous knowledge systems (IKS) strongly influenced the approach and content used in the CR course. See Appendix E-Sample Curriculum and Appendix F-Syllabus, Contract, Schedule.

To begin with, the culturally responsive teacher *'character profile'* (Gay 2010, 45) was used as a checklist to analyze the CR course materials. Recall the following criteria list was previously cited in Section 3.2.1 on page 48 of this paper in greater detail. The table below is a correlation between the CRT 'character profile' and the CR course content and strategies:

Table 46 - Links between Culturally Responsive Teaching 'Character Profile' (Gay, 2010, 36-36) and the CR course in this study

CRT Teaching *Character Profile Descriptors*:	CR course:	Evidence Shown By:
Validating	✓	Consistently including examples from diverse cultures for example, names of celestial objects. Many names of bright stars are in Arabic, many Greek zodiacal constellations were borrowed from Babylonia (present day Iraq). In addition, inclusion of Indigenous star names like *Ikwe Anung*-Women's Star from Ojibwe or *Anpetu Luta*-Red Day Star from D/Lakota.
Comprehensive and Inclusive	✓	Prioritize creation of a community learning environment. Nearly every class over the semester has at least some component of group work, even lectures have ten minutes of extra practice problems, where group work is encouraged. Workshop model.
Multidimensional	✓	The foundational content is astronomy, but CR course also included broader, topics such as: science and society; chemistry, biology, geology, cultural astronomy, history of science, current news, economics, art and so on. The emphasis is on how a set of key ideas in astronomy are connected to the big picture as opposed to an enormous collection of unrelated ideas. The CR class weaves the most densely interesting ideas together in one tapestry.

Empowering	✓	The CR course consisted of four non-cumulative parts; four deadlines. Work at your own pace. Participatory In-Class Activities provides immediate ongoing assessment, practice to try out ideas learned, and opportunities to build confidence.
Transformative	✓	Discussions, case studies, and an emphasis on critical thinking promotes students to practice oral and written communication skills but also to reflect on why they think what they think. For example, *Would You Go on a One-way Mission to Mars* or *Do You Believe in Extraterrestrial Life*
Emancipatory	✓	Use of textbook as an encyclopedic resource, not driving content but supporting learning. Use of news and research articles to stay relevant and discuss answered questions. Find your own voice, your own interests. Also flexible grading and group work often builds a sense of all students as 'A' students.
Humanistic	✓	Emphasis on human welfare, dignity, and interconnectedness of humanity. An example here is the night sky and the potential loss of dark night skies. This discussion is rich with layers rooted in ethnicity/race, personal experience, economics, health, spiritual and religious beliefs. *Are dark skies going extinct? Does artificial lighting at night cause cancer….?*
Normative and Ethical	✓	Acknowledging both Western European science and other Indigenous science systems, allows students to see science as a cultural enterprise. Teaching the scientific method as an idealized norm, highlighting where it fails.

As illustrated in Table 46, all eight (or 100%) of the descriptors that comprise the *'character profile'* of culturally responsive teaching are embedded in the uniquely designed introductory astronomy course. Thus, the CR course that is the cornerstone of this study was embedded with transformed content and an innovative approach that is in clear agreement with culturally responsive pedagogy (CRP).

Next, recall the '*seven elements of culturally relevant pedagogy'* (Ladson-Billings, 2006, 30-37). Note that the following list was previously cited in Section 3.2.1 on page 46 of this dissertation in more detail. Correlation between the 'seven elements' and the CR course are presented in the table below:

Table 47 - Summary of Links between Culturally Relevant Pedagogy and CR course

Seven Elements of Culturally Relevant Pedagogy:	CR course:	Evidence Shown By:
Social Contexts	✓	Included in Discussions and some lectures, for example women in science Jocelyn Bell Burnell and the Human Computers of NASA
Students	✓	Flexible grading combined with a high standard; balance of structure and suppleness; learn to learn
Curriculum	✓	Constantly deconstructing, constructing, and reconstructing; Design original content
Instruction	✓	Wide variety of different techniques and strategies; Activities that begin with wide-open questions, Textbook as encyclopedia, less emphasis on memorization of facts
Academic Achievement	✓	Demand excellence and rigor, but allow for life. Flexible grading, Lowest 15% dropped, Extra credit
Cultural Competence	✓	Include content from non-Eurocentric cultures especially related to night sky; More diverse representation scientists; Use of Discussions to

		analyze individual beliefs versus group perspectives
Sociopolitical Consciousness	✓	Included in Discussions and News updates, for example, Space X, the space economy, and space tourism

To be clear, all of the 'seven elements of culturally relevant pedagogy' were a part of the CR course. The two elements had the least emphasis were 'Social Contexts' and 'Sociopolitical Consciousness' although both were often included in Discussions.

To conclude, the final table connects the culturally responsive (CR) course in this study to the learning styles based on Indigenous knowledge systems (IKS) using the literature review of Castagno and Brayboy (2008, 954). Note that the following table was previously cited as Table 3 in Chapter 3: Theoretical Frameworks (see p. 50 of the thesis).

Table 48 - How Indigenous Learning Styles are Different from Mainstream Learning Styles in the U.S. (Castagno and Brayboy 2008, 954)

Learning styles for Indigenous Youth:	CR course:	Method and Approach:	Specific Content Examples:
visual	✓	Use of star maps; Use of iconic astronomical images; Reading diagrams, graphs, charts, etc.	*Current Night Sky* Activities Photo Gallery – *What's the Big Idea.*
hands-on	✓	Use of demonstrations to help the ideas become more tangible	Physics examples include: the spinning chair; diffraction grating to show spectra, ionized gas tubes, etc.
connecting to real-life	✓	Use of discussion-both in class and at home, individual and small group; Use of news stories and current research	At Home Activity- *Science in Your Life-Would Your Life Be Any Different Without Science* (3M Study, 2018)
direct experience	✓	Use of samples that directly relate to the stories and ideas woven into lecture	Samples shared include: prisms, florescent minerals, infrared camera, trilobite fossil, meteorite, etc.
participating in real-world activities	✓	Discussion; News events; Use of Citizen Science; Planetarium events; Star gazing	Discussion-*What is Your Connection to the Stars*? Discussion- *End of Night?! (addressing light pollution)*
global	✓	Discussion; News events; Lectures	Discussion-*Space travel Anyone?*; S. Hawking quote regarding aliens; Gene editing- CRISPR
seeing the overall picture before the details	✓	One semester divided into four non-cumulative parts; Each part focused around a key theme; Discussions at the beginning of each part acknowledge a person's prior experience; Night sky-constellations as a framework	Photo Gallery – *What's the Big Idea- Do You Believe; Current Night Sky – North and Spring; Part 1 – Where Are We?*
creative	✓	Original content design; Keenly listening and aware of students' vibe, ready to adapt; Case studies or questions with no wrong answer.	Small Group Discussion-*Parallel Universes – What to Say to the Other You; Should NASA be allowed to open up a stable worm hole in our Solar System?*
holistic	✓	Connect ideas to other ideas, avoid isolated facts and too much emphasis on route memorization.	Lecture topic - *Where did the air you breathe come from?* ties together solar nebula, primary

		Strong use of narrative pedagogy and the big picture.	atmosphere, cyanobacteria, rusting of Earth (place-based samples), etc.
reflective	✓	Emphasis on critical thinking and personal experience.	Case studies – *What is the Action Plan for when First Contact (with Aliens) Happens*
collaborative	✓	Frequent use of group work, sometimes mandatory; sometimes optional	Discussions; Talk to Your Neighbor extra practice; In-Class Activities
circular	✓	Use of astronomical photos that are mentioned in layers, woven into a tapestry for each part.	Seasonal connection to night sky; Ideas mentioned in different contexts; Night sky objects anchor more abstract astronomical theories
imaginal	✓	Use of narrative pedagogy, especially in lectures.	Discussion – *What is Life? How Do You Imagine (Alien) Life?*
concrete	✓	In Class Activities; Current Night Sky	Motion of the Moon; Motion of the Sun;
simultaneous processing	✓	Emphasis on 'big idea'; use of 3-5 ideas that show relationships in each part	Combined use of Night Sky and Photo Gallery-*What's the Big Idea*
observation precedes performance	✓	Lab-like activities collect data from Planetarium software or data table.	In Class Activity – *Motion of the North Star,* collect data on how Polaris is moving over the centuries and millennium
naturalistic	✓	Relates to sky, earth, air, land, energy, weather. Four elements.	*Current Night Sky Activities; Lecture topics like Space weather; Primordial life in ocean, Great Oxygen Event, the Cambrian, etc.*

Here again, all seventeen (or 100%) Indigenous learning styles are represented in the uniquely designed culturally responsive (CR) introductory astronomy course used in this study.

Other relevant methodology:

- Four parts. A sixteen week semester is divided into four equal parts, each with one big picture idea: *Where Are We? Are We Alone? Will the Sun Become a Black Hole? What is the Fate of the Universe?* These are not cumulative over the semester. Less emphasis on memorization, more emphasis on how ideas are connected, relevant, and interesting. Appendix F- Syllabus, Contract, Schedule
- High level of Accountability. Almost every class has an associated grade item. For example, the grade item for the In Class Discussion-*Do You Believe*? would be based on the completed work turned in at the end of class, the grade item for the In Class Activity-*Kepler's Laws* would be a corresponding online quiz that mirrors the worksheets completed in class, the grade item for the Lecture-*Orbiting* would be 3-5 extra practice problems completed the last 5-10 minutes of class, and the grade item for the Current *Night Sky-Fall & Summer Stars* activity would be the graded hard copy of a completed star map that would then open an associated online quiz. See Appendix F- Syllabus, Contract, Schedule
- Community classroom built on relationships. Emphasis on what is said and done in person.
- Increased Creativity. Video project, discussions, variation in course delivery, open ended questions, connections in art, trying out new curriculum or approaches.

- Storytelling Pedagogy. In Indigenous knowledge systems, storytelling activates all four parts, mind-body-heart-spirit (Simonelli 1994) as compared to lecture that is more similar to textbook reading and has a central focus on the mind and the physical act of reading.

6.5 Limitations of this Study

These findings are exploratory in that they represent student experiences in four college level introductory astronomy courses taught by one instructor with high competency in implementing active learning in a large 'lecture' classroom. Several limitations apply to this study. The first limitation was a small sample size of students (n = 459). Ideally a larger sample size would yield larger data sets and more robust statistical analysis. An area for future exploration would be scalability. Another limitation was that there was only a single-institution involved in the study, and the study was carried out within a single STEM discipline, astronomy. It would be interesting to see if similar results would emerge with different instructors. There is growing literature on the effect of faculty as role-models for students, especially for female students in STEM (Bettinger and Long 2005). The question of transferability is left unanswered. Would there be similar findings at a different type of institution? This study was carried out at a regional comprehensive Midwest university. And finally would the ethnic and racial make-up of the students and the instructor affect the outcomes (i.e. a more racially diverse student population and a less diverse instructor) (Dee 2005).

One possible limitation is the question of 'To what extent is the control course truly a control?' In other words, how much of the increased engagement and learning gains can reliably be attributed to the CRP in the CR course?

The analysis showed that, although the treatment course (CR) did have slightly more activity than the control (IE) course (students Receiving 10.6% less; instructor Presenting 5.6% less), this was not statistically significant. The analysis showed that what was different in the two courses was more time spent on students' working and instructor guiding in the CR course, which suggested greater student engagement in learning. This was borne out in the analysis of level of engagement, which shows that a greater % of the students in the CR class were engaged in learning. This is especially significant considering that the CR class was much larger.

The increased engagement and learning gains may be explained by the nature of the CR-inspired activities. For example, more traditional active learning worksheets or 'cookie cutter' lab activities might require students to be active, but would not necessarily result in increased learning and engagement. On the other hand, when increased cultural responsiveness is used both in the curriculum and teaching strategies, it demands not only greater activity but that endeavor is more ethnically diverse, more socially relevant, more creatively conceived, than traditional teaching and active learning. Recall Ladson-Billings (1995) defines three key elements of culturally relevant pedagogy: academic success, cultural competence, and challenge the status quo. Culturally relevant pedagogy and culturally responsive pedagogy inspired by Indigenous knowledge systems activates the brain and body, but will encompass our humanity and creativity as well.

The overriding question here is: to what extent can the results of this study be generalized? The intent is that these conclusions will inspire additional studies and provide a forum and a framework for broader discussion and a more in depth understanding of the factors that predict student engagement and learning gains, particularly as related to inclusion of all students in STEM higher education course experiences.

Chapter 7: Conclusion

Summary of Major Findings. This study compared student learning and engagement gains between two distinctly different types of instructional methods in an introductory college level astronomy course. Both courses implemented traditional (T) instructor-centered learning and interactive engagement (IE) student-centered learning deliveries. Both courses were taught by the same instructor that met three times a week for 50 minutes each over a 15-week semester. These were general education courses and not intended for majors. The study compared the students' performance between the course with increased culturally responsive (CR) pedagogy (i.e. treatment course), and the control course. Although the core science content was similar, the CR course used both curriculum and delivery methods derived from culturally responsive pedagogy (CRP). The key innovation of this study involved course design in the intervention class that used a culturally responsive framework.

The hypothesis of this study - that both higher engagement and positive learning gains will occur in the culturally responsive class - was found to be true. Students in the culturally responsive (CR) course learned more and experienced greater engagement than their peers in the control course. In addition, the underrepresented minority (URM) students in the culturally responsive (CR) course performed exceptionally well. By one measure, (the pre-post concept inventory gain), the URM students in the CR course outperformed *all* other students in the study, including majority and minority, IE (control) and CR (treatment) courses. By letter grades, URM students in the culturally responsive (CR) course were nearly *eight times* more likely to earn an 'A' as a final course grade as compared to URM students in the IE (control) course. One surprising result was that *female* underrepresented minority (URM) students in the culturally responsive (CR) course achieved very significant learning gains. For example, the final course grades for female URM students in the CR course were nearly 10 percentage points or one letter grade higher than female URM students in the IE (control) course.

The results of this work were closely organized around the following specific research questions:

- *Will students find ASTR 101 more engaging if the content is more culturally relevant?* (RQ1)
- *How does culturally inclusive curriculum quantitatively and qualitatively affect knowledge acquisition for ASTR 101 students?* (RQ2)
- *Will underrepresented minority students be positively affected by teaching ASTR 101 with increased culturally responsive pedagogy?* (RQ3)

Utility of Data Collections Methods. The case for increased cultural responsiveness in the introductory college-level non major astronomy course ultimately rests on the empirical measurements of effectiveness based on the students' performance and satisfaction. Over the course of this study a broad spectrum of evidence was analyzed in order to make the relevant conclusions, including both quantitative and qualitative data. To measure learning gains (RQ2) two common instruments were used: course grades and the astronomy concept inventory (ADT), where pre and post scores were used to measure normalized gain. To measure engagement (RQ1) the following tools were used: COPUS classroom observation protocol, student anonymous surveys, and student interviews. The interviews allowed for a more nuanced understanding of the students' experiences in the course with increased culturally responsive (CR) pedagogy. In addition to the learning gains that were precisely measured by the ADT concept inventory, this tool provided the indispensable demographic information, particularly the ethnicity and sex of student participants that allowed for a direct comparison of learning gains (RQ3). Final course grades added another layer to the understanding of the students' science knowledge gain. The multiple anonymous student surveys at the end of selected classes scattered throughout the semester gave direct feedback and allowed for both quantitative and qualitative aspects of student perceptions to be heard. And finally, the in-depth student interviews provided a key layer of depth to the dynamics of the student experience. The students interviewed offered many insights such as: excitement of experiencing the night sky, the essentialness of the small group discussions, the thrill of knowing the stories layered in the astronomical images, the multiple perspectives in a class of nearly 200 students, and the perception of the instructor caring.

Without a doubt the Classroom Observation Protocol for Undergraduate STEM (COPUS) instrument provided a clear and direct measure of behavior in the undergraduate science classroom. This practice and implementation is an important step forward in creating a baseline of instructional methods, instructor-based versus student-centered, and promoting more effective interactive engagement in departments, institutions, nationally and beyond. However, based on the research results found in this study, it would be useful to modify the observation protocol to also be able to codify cultural relevancy in student and instructor interactions. For example, to measure the depth of learning, the ownership of knowing, how the knowledge is used outside and after the class, the excitement level in the classroom, the relationships, the inclusivity and diversity of thought or simply put the uniquely human factors in learning. An ideal classroom observation would aim to characterize and codify beyond the superficial.

Future Research Directions. Students in the treatment course reported more positive perceptions of learning, greater enjoyment of learning, increased class satisfaction, along with greater science learning gains than their peers in the control course. More to the point, this study was not comparing active learning (interactive engagement) to lecture-only courses (as in Deslauriers et al.). Rather, this study was comparing two courses that both implemented traditional (T) lecture-based and interactive engagement (IE) student-centered learning deliveries to good effect. What was compared was the increased culturally responsive pedagogy in one of the introductory STEM college courses. Here is where the more *uniquely human skills* (such as communication, teamwork, intercultural/global fluency, innovation, and creativity) were allowed to infiltrate the course. Only when the teaching and learning tapestry was woven with *both,* (science content learning and the uniquely human part), authentic relationships were forged and maximum learning occurred.

These positive relationships, (caring and engaging), created a thriving classroom community of learning that served as the bedrock for knowledge acquisition, a place where students were motivated to choose academic excellence. Here is where the blended educational model of Eurocentric and Indigenous scientific knowledge approaches such as, *Etuaptmumk*-Two Eyed Seeing (Marshall 2004), allowed the best of both worldviews to take root. Remarkably, the results of this study found *the role of culture as a variable in learning science is tremendously important.* Indeed, using a method and approach infused with culturally responsive pedagogy, inspired by Indigenous knowledge systems, was found to be a superior vehicle for engaging students. These more balanced, more inclusive dynamics benefited all students, and underrepresented minority students disproportionately excelled.

Finally, it is important to note that these results are exploratory. It would be meaningful to determine the extent to which the demographics of the students and instructor could influence outcome, along with the type of institution, geographical location, STEM discipline, and classroom setting. Recollect that in this study there were nearly 200 students in the CR course, or the treatment course, (as compared to the control course of 60 students), and it was held in a fixed seating large lecture auditorium. Future research that illuminates the nature of relationships in the learning environment, the emotions of learning, and the bridge between the sciences and humanities will provide a useful next step.

Based on the current crises in the U.S. workforce (LaPrade et al. 2019; Deming and Noray 2018), the U.S. higher education (Carlson 2018; Christensen 2013; McGowan 2019; Selingo 2018), and in STEM education (Manduca et al. 2017; Deming and Noray 2018) it is time to widen the approach to teaching and learning in STEM higher education. A historical look at the origins of the university system and of western European science clearly shows a one culture, one class, one gender approach. Recall the original university system (based in England) was meant for the top 24% of society (Aikenhead 2017a). A look at the present day higher education system clearly shows monumental changes including: globalization, technology, personalization, looped learning, and the internet - all of which have led to the massification and diversification of post-secondary education. And yet 55% of STEM classrooms in the U.S. are still using eighty percent of their class time in lecturing format (Stains et al. 2018). This mismatch demands an update, a re-calibration of the very definition of what teaching and learning means in STEM higher education. It makes sense that students in general education college-level introductory STEM courses are not necessarily preparing for discipline-based graduate school, but definitely preparing for life, work, wellness, and civic participation. In this sense culturally responsive, Indigenous knowledge systems inspired, active learning STEM education is empowering for all.

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The Effects on Student Knowledge and Engagement When Using a Culturally Responsive Framework to Teach ASTR101

Annette S. Lee

APPENDIX

Appendix A – Ethical Clearance - Internal Review Board (IRB) – Sample Documents

Culture and STEM in the Introductory Astronomy College Classroom
Implied Informed Consent

You are invited to participate in this study to determine best practices and effectiveness for teaching and learning astronomy. You were selected as a possible participant because you are a student in an introductory astronomy class at (name of university). This research project is being conducted by Professor (name of professor), for dissertation work in astronomy education research (AER).

Background Information and Purpose

The purpose of this study is to improve student engagement and success in the introductory astronomy college classroom.

Procedures

(1) Surveys - If you decide to participate, you will be asked to complete an Anonymous Survey after some class activities. On each Survey there will be two boxes on the bottom (or something similar on a D2L Anonymous Survey) for you to choose if you do not want your data to be used in the research. One box will be for the general 'opt-out'; a second box will be for anyone under 18 years old. In both cases your data will not be used as part of this study.

(2) Observers - During the semester for approximately 5-10 classes there will be a pair of observers attending the class. They will sit quietly and observe the class while taking details notes about what the instructor is doing and what the students are doing. After they are introduced, please ignore them.

(3) Interviews - Towards the end of the semester there will be a call for 5-10 volunteers for a 15-20 minute interview after the class has ended. This is completely voluntary. The interview is not related to the course content but rather the experience of the class. All students are welcome to participate.

Risks

There are no foreseeable risks associated with participation in this study.

Benefits

Benefits of the research will be to help gauge the effectiveness of curriculum and teaching strategies in this class, ultimately for increasing student engagement and student success.

Confidentiality

Your information will be confidential and no answers that could identify a specific individual will be used. Only comparison of groups will be analyzed.

Research Results

If you are interested in learning the results of the survey, feel free to contact the researcher at (phone) or go to the Department of Physics and Astronomy Office at (address).

Contact Information

If you have any additional questions please contact the researcher, (name of researcher), at (email) or (phone).

Voluntary Participation/Withdrawal

Participation is voluntary. Your decision whether or not to participate will not affect your current or future relations with (name of university) the instructor, or your grade. If you decide to participate, you are free to withdraw at any time without penalty.

Release Form for Use of Photograph/Video/Audio Recording

"Culture and STEM in the Introductory Astronomy College Classroom-Full Study of Approach and Instruments"

Professor (name)
(email and phone)

Please Print:

____
Participant Name

____
Legal Representative if Applicable

This form asks for your consent to use media for and from this study. We would like you to indicate how we can use your media. On the next page is a list of media types that we will use. Please initial where you consent for that type of use of your media. Legal representative initials will provide consent when needed.

Regardless of your answers on the next page, you will not be penalized.

We will not use your media in any way you have not initialed.

Questions regarding this form should be directed to the researchers. Additional answers can be found by contacting the IRB Administrator or an IRB Committee Member. Current membership is available at: (website).

A copy of this form will be provided for your records.

Audio; no video	
Consent Granted	Type of Release
	Used by research team to record and analyze data
	Published or presented in an academic outlet (e.g., journal, conference)
	Played at a nonprofessional venue (nonscientific group)

Transcription of audio	
Consent Granted	Type of Release
	Used by research team to record and analyze data
	Published or presented in an academic outlet (e.g., journal, conference)
	Presented at a nonprofessional venue (nonscientific group)

I have read the above carefully and give my consent only for those items in which I initialed.

Participant Signature (if 18 years of age or older) Date

Participant Name (Printed)

WHEN CONSENT IS NEEDED FROM A LEGAL REPRESENTATIVE, COMPLETE THIS SECTION. UP TO TWO LEGAL REPRESENTATIVE MAY SIGN.

Legal Representative Signature Date

Legal Representative Name (Printed)

Second Legal Representative Signature Date

Second Legal Representative Name (Printed)

Appendix B – COPUS Observer's Coding Form

Date: _______ Class: _____________ Instructor: _______________________
 # students _______ Observer Name: _____________________ Time span ________________

Collapsed Codes ->Individual Codes

STUDENTS

R Receiving	L: Listening to instructor V: Viewing visuals
STC Talking to Class	AnQ: Student answering question posed by instructor SQ: Student asks question WC: Students engaged in whole-class discussion SP: Students presenting to entire class
SW Student Working	Ind: Individual thinking/problem solving WG: Working in groups on worksheet activity OG: Other assigned group activity Prd: Making a prediction about a demo or experiment TQ: Test or quiz
O Other	W: Waiting (instructor late, working on fixing technical problems) O: Other

FACULTY

P Presenting	Lec: Lecturing or presenting information RtW: Real-time writing D/V: Showing or conducting a demo, experiment, or simulation
G Guiding	FlUp: Follow-up/feedback on clicker question or activity PQ: Posing question to students (nonrhetorical) AnQ: Listening to and answering student questions to entire class MG: Moving through class guiding ongoing student work 1o1: One-on-one extended discussion with individual students
A Administration	Adm: Administration (assign homework, return tests, etc.)
O Other	W: Waiting (instructor late, working on fixing technical problems) O: Other

	Students				Faculty				Engagement			Comments
min	R	STC	SW	O	P	G	A	O	L	M	H	
1												
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20												
21												
22												
23												
24												
25												

Other Notes:

	Students				**Faculty**				**Engagement**			**Comments**
min	R	STC	SW	O	P	G	A	O	L	M	H	
26												
27												
28												
29												
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47												
48												
49												
50												

Collapsed Codes ->Individual Codes

STUDENTS

R Receiving	L: Listening to instructor V: Viewing visuals
STC Talking to Class	AnQ: Student answering question posed by instructor SQ: Student asks question WC: Students engaged in whole-class discussion SP: Students presenting to entire class
SW Student Working	Ind: Individual thinking/problem solving WG: Working in groups on worksheet activity OG: Other assigned group activity Prd: Making a prediction about a demo or experiment TQ: Test or quiz
O Other	W: Waiting (instructor late, working on fixing technical problems) O: Other

FACULTY

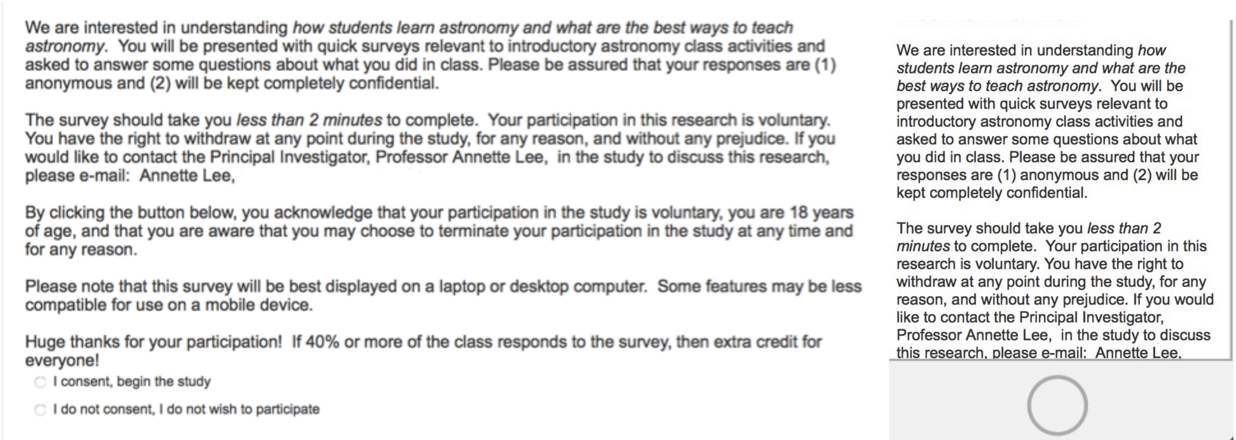
P Presenting	Lec: Lecturing or presenting information RtW: Real-time writing D/V: Showing or conducting a demo, experiment, or simulation
G Guiding	FlUp: Follow-up/feedback on clicker question or activity PQ: Posing question to students (nonrhetorical) AnQ: Listening to and answering student questions to entire class MG: Moving through class guiding ongoing student work 1o1: One-on-one extended discussion with individual students
A Administration	Adm: Administration (assign homework, return tests, etc.)
O Other	W: Waiting (instructor late, working on fixing technical problems) O: Other

For each 1 minute interval, check columns to show what's happening in each category. Check multiple columns where appropriate.
Start at the beginning of each class, code A if passing our papers

Engagement (more than attentive listening)

L Small fraction of students (10-20%) obviously engaged.
M Substantial fractions both clearly engaged and clearly not engaged. 50/50
H Large fraction of students (80+%) clearly engaged in class activity or listening to instructor.

Appendix C – Survey Instrument – Sample Documents


We are interested in understanding *how students learn astronomy and what are the best ways to teach astronomy*. You will be presented with quick surveys relevant to introductory astronomy class activities and asked to answer some questions about what you did in class. Please be assured that your responses are (1) anonymous and (2) will be kept completely confidential.

The survey should take you *less than 2 minutes* to complete. Your participation in this research is voluntary. You have the right to withdraw at any point during the study, for any reason, and without any prejudice. If you would like to contact the Principal Investigator, Professor Annette Lee, in the study to discuss this research, please e-mail: Annette Lee,

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

Please note that this survey will be best displayed on a laptop or desktop computer. Some features may be less compatible for use on a mobile device.

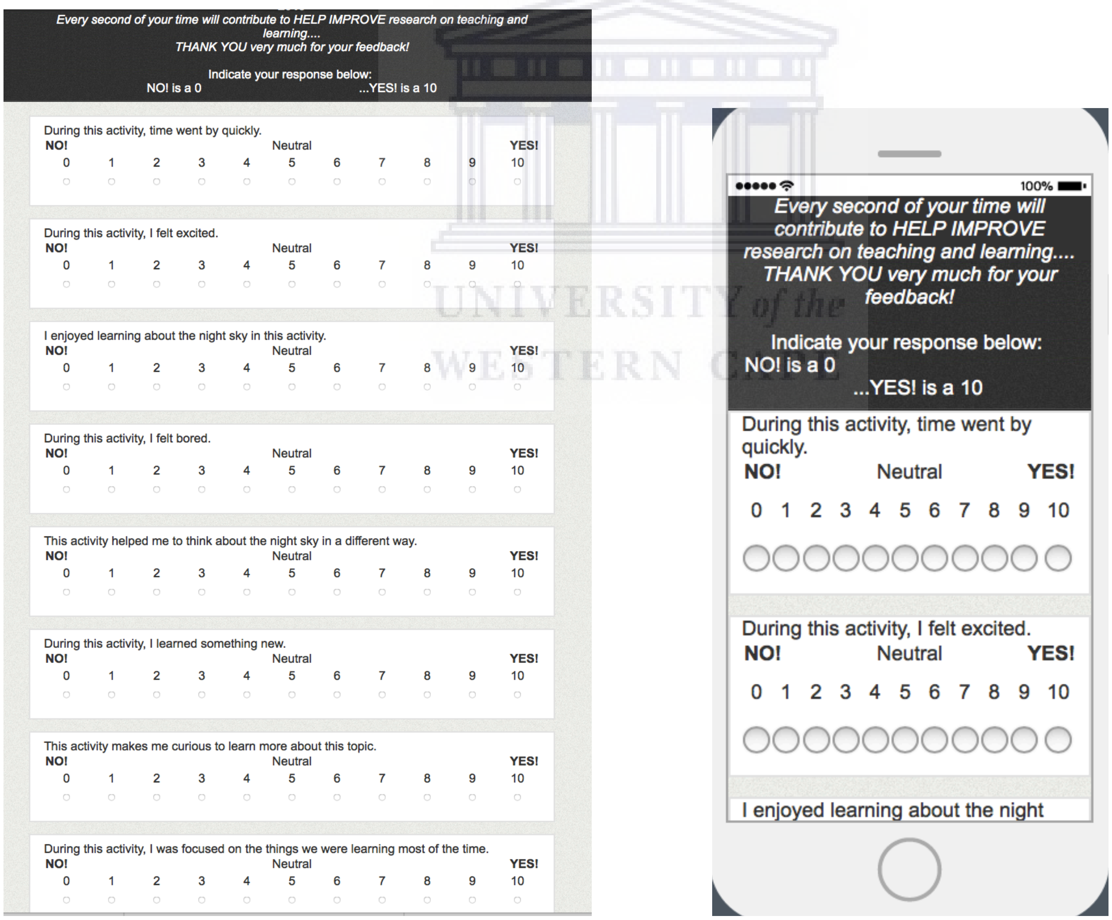
Huge thanks for your participation! If 40% or more of the class responds to the survey, then extra credit for everyone!

- I consent, begin the study
- I do not consent, I do not wish to participate

We are interested in understanding *how students learn astronomy and what are the best ways to teach astronomy*. You will be presented with quick surveys relevant to introductory astronomy class activities and asked to answer some questions about what you did in class. Please be assured that your responses are (1) anonymous and (2) will be kept completely confidential.

The survey should take you *less than 2 minutes* to complete. Your participation in this research is voluntary. You have the right to withdraw at any point during the study, for any reason, and without any prejudice. If you would like to contact the Principal Investigator, Professor Annette Lee, in the study to discuss this research, please e-mail: Annette Lee,

Figure 40-Anonymous Student Survey, consent


Every second of your time will contribute to HELP IMPROVE research on teaching and learning....
THANK YOU very much for your feedback!

Indicate your response below:
NO! is a 0 ...YES! is a 10

During this activity, time went by quickly.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

During this activity, I felt excited.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

I enjoyed learning about the night sky in this activity.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

During this activity, I felt bored.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

This activity helped me to think about the night sky in a different way.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

During this activity, I learned something new.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

This activity makes me curious to learn more about this topic.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

During this activity, I was focused on the things we were learning most of the time.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

100%
Every second of your time will contribute to HELP IMPROVE research on teaching and learning.... THANK YOU very much for your feedback!

Indicate your response below:
NO! is a 0
...YES! is a 10

During this activity, time went by quickly.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

During this activity, I felt excited.
NO! Neutral YES!
0 1 2 3 4 5 6 7 8 9 10

I enjoyed learning about the night

Figure 41 – Anonymous Student Survey, online

MASTER LIST OF QUESTIONS-

ASTR 101 WITH CULTURAL RELEVANCE SURVEY

A. ENGAGEMENT- 4 questions
B. KNOWLEDGE AQUISTION – 2 questions
C. NIGHT SKY – 1 question
D. SCIENCE AND SOCIETY-3 questions
E. VISUAL LANGUAGE – 1 question
F. ALL SURVEY-GENERAL – 4 questions…………………..15 questions Total

---

A. ENGAGEMENT (modified version based on "The Science Learning Activation Lab-Measures Technical Brief-Engagement in Science Learning Activities, v3.2, Aug. 2016)

1. *During this activity, I felt bored.*

2. *During this activity, I felt excited.*

3. *During this activity, I was focused on the things we were learning most of the time.*

4. *During this activity, time went by quickly.*

B. KNOWLEDGE AQUISTION & EFFECTIVE COMMUNICATION

5. *I was confident communicating the ideas in this activity.*

6. *During this activity, I learned something new.*

C. NIGHT SKY (modified from "Noctcaelador Inventory" William Kelly, 2006)

7. *I enjoyed learning about the night (or day sky) in this activity.*

D. SCIENCE AND SOCIETY (modified from "Astronomy Attitudes Survey", by M. Zeilik, 2012)

8. *This activity made me think about science in a different way.*

9. *This activity will affect how I see the world around me.*

10. *I like that this activity had multiple perspectives.*

11. *Participating in this activity made me feel more a sense of belonging in this class.*

E. VISUAL LANGUAGE & CREATIVITY

12. I liked that this activity used pictures to explain the topic.

F. ALL SURVEYS – GENERAL PURPOSE

13. This activity makes me curious to learn more about this topic.

14. In general, I find astronomy(Very Interesting, Interesting, Boring, Hate it).

15. On a scale from 0 to 10, how likely are you to recommend this activity to a friend taking intro astronomy? Use the slider to move the gauge, for example: 0-Terrible waste of time..........10- Highly recommend…

16. Any other comments…

Appendix D – Interview Materials

Astronomy Education Research (AER) - Interview Questions:

Approximately 5-10 students will participate in one 15-20-minute semi scripted interview. Students will have previously taken (name of instructor) (name of course) course and at least one other college class. The emphasis of these interviews is to compare the classroom experience and level of engagement in (name of instructor's) class to other college classes the student has taken. Students will be interviewed by (name of instructor) and a strong effort will be made at the beginning of the interview to emphasize that giving an honest summary of their personal experience in astronomy class (as opposed to science content) is most valuable. There is no single 'right' answer. Students will be recruited by the following methods: announcements in class, posting on the class D2L homepage, only if needed emails to the entire class will be sent out. Interviews will be semi-scripted to allow for student's voice to be heard and followed in a conversational manner. Audio recording of the interview will allow for re-listening to interviews as needed. All student participating in the interview will receive a $40 VISA gift card and have the option to review a MP3 file of their recording.

Sample questions include:

1. *What was your experience of the class? (explore as needed….open ended, let students talk here…)*
2. *Was this class different from other classes you have taken?*
3. *How would you describe your interest in astronomy prior to this class?... How would you describe your interest in astronomy after this class*
4. *Why did you choose to take this class?*
5. *Did you get what you wanted out of the class?*
6. *Were there new experiences in this class?*
7. *Did anything change for you?*
8. *Did your view of science/understanding of science change at all after taking this class?*
9. *Has this course changed the way you experience the night sky?-(probe for specific moments, experiences provided as part of the class)*
10. *Did you feel a sense of belonging/community/included.. in this class? …and in relation to other classes?*
11. *What would you like to learn more about in astronomy for own interest? (relate the content to themselves)..*

"Culture and STEM in the Introductory Astronomy College Classroom"
Consent to Participate

You are invited to participate in a research study about teaching and learning in introductory astronomy.

If you agree to be part of the research study, you will be asked to answer questions in a 15-20 minute interview the semester following having taken the class taught by (name of instructor).

Benefits of the research improve teaching and learning in introductory astronomy; widen participation in STEM; complete assessment of cultural relevancy in introductory astronomy that is part of dissertation work in Astronomy Education Research (AER).

Risks and discomforts – None.

Data collected will remain anonymous. An example for interviews, responses will be kept strictly confidential, your name will not be disclosed. During the interview you may refuse to answer any questions. After the completion of the interviews, you have the option to receive your transcribed interview. At this point, if you wish to make expand responses or note omissions to the transcription, you may.

Participating in this study is completely voluntary. Your decision whether or not to participate will not affect your current or future relations with St. Cloud State University, or the researcher. If you decide to participate, you are free to withdraw at any time without penalty.

If you have questions about this research study, you may contact (name of instructor), (email), (phone). Results of the study can be requested from the researcher (name of instructor)

If you choose to participate, you will be compensated by: a $40 Visa gift card immediately after completing the interview.

Your signature indicates that you are at least 18 years of age, you have read the information provided above, and you have consent to participate.

____ _______________________

Signature Date

* All interviewees will be 18 years old or greater.

Sample email invitation to (name of course) students to participation in voluntary Interview:

Hello (Student's Name). This is your former ASTR 107 instructor, (name of instructor). As you may remember I am very involved in research on how students learn astronomy, 'Astronomy Education Research AER'. In these continuing efforts, I am looking for 5-10 students to participate in a 15-minute interview about your personal experience in (name of course) last semester/year. Please let me know if you are interested in participating by sending an email response to: (email)
You will receive a $40 Visa gift card at the end of the interview. Interviews will be audio recorded for review purposes and you can certainly get a copy of the audio file.

Thank you for considering.
(name of instructor)
(email of instructor)

Appendix E – Sample Curriculum

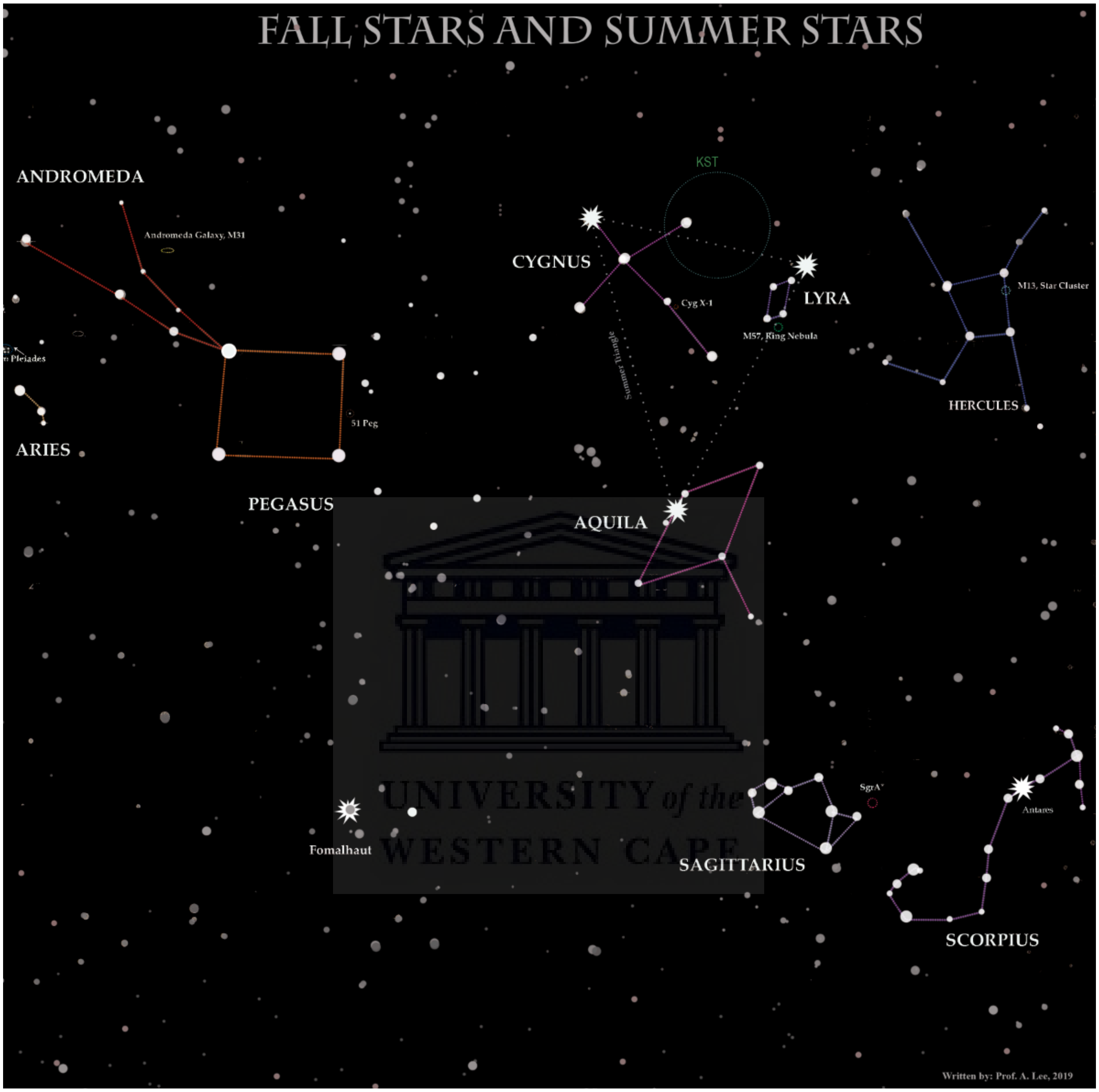


Figure 42 – Current Night Sky – Fall and Summer Stars, Lee 2019, sample curriculum with increased cultural relevancy used in the CR course

Figure 43 – What's the Big Idea: Do You Believe?, sample curriculum with increased cultural relevancy used in the CR course

LAB – THE MOTION OF the NORTH STAR & the THUNDERBIRD

PART I –INTRODUCTION

Fig.1-- Panorama photography taken during a lightning storm over Bucharest, Romania, wikipedia

In one second or less, a lightning bolt only 1 inch in diameter strikes the surface of the Earth from the clouds. An electrical discharge takes place. Only about 25% of the lightning strikes reach the ground. Thunder is the sound made by lightning. Suddenly the air 'inside' the lightning bolt experiences a quick increase in pressure and temperature. This causes the air to expand and collide with the surrounding air. The collision of two air fronts creates the sound, a 'sonic boom' or 'thunderclap'. Lighting has three important connections here: (1) fires, (2) nitrogen, and (3) origins of life.

Many cultures have stories and teachings about the Thunderbird, for example an Ojibwe story about the Thunderbirds called 'Thunderstrike' (Fig. 2). In D/Lakota (and also Ininew), there is a Thunderbird constellation, called *Wakinyan*. (Fig. 3). The word "*Wakan*", is translated as "sacred" but as stated by Lakota elder, Albert Whitehat Sr., the word is more correctly translated as 'the power to create; the power to destroy', like a double edged sword. Thunderbirds and Thunderbeings are often described as 'keepers of truth', protectors, and watchers of men (Ref.) The idea of 'walk in a good way, because the Thunderbeings are always watching' is sometimes heard.

Polaris, or the North Star, is seen in the night skies of the Northern Hemisphere directly above the Earth's north rotational axis, or North Pole. It is with 1 degree of the exact 'motionless point' or the North Celestial Pole (NCP). Historically used for navigation due to the stars' altitude being a reflection of the viewers' latitude. As viewed from ground, it is the only star in the sky that appears motionless (for Northern Hemisphere stargazers).

What is the connection between the motion of the North Star and the Lakota Thunderbird?

Fig 2- Thunderbird story, E. LaPensee

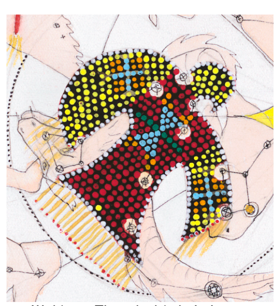


Fig 3-*Wakiyan-Thunderbird*, A. Lee, 2012

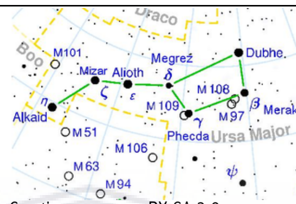
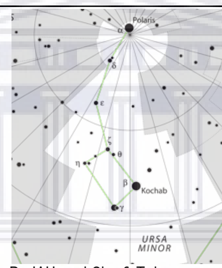
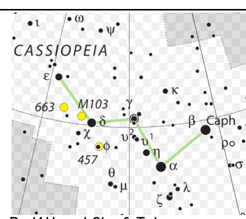
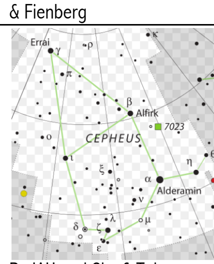
Fig 4- Star trails photo, Polaris at center, A. Dace

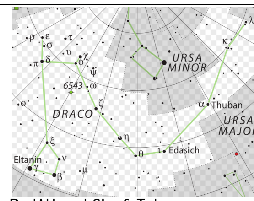
PART II –STAR MAP

1. Using the star chart "SCOO2T CONSTELLATION CHART-NORTH CIRCUMPOLAR REGION-EPOCH 2000" (last page), identify the following items.

- ☐ Connect stars with a stick figure, circle individual stars.
- ☐ Write the name of each object nearby.

Table 49- Table of celestial objects. Constellations (and constellation nicknames) in caps. Star Names in italics.

Object	**Description**	**Details** (all images from wikipedia)	**Indicated on the Star Map**
BIG DIPPER	Nickname for the 7 brightest stars in Ursa Major (Greek culture)	 Creative commons: BY-SA 3.0	☐
LITTLE DIPPER	Nickname for the 7 brightest stars in Ursa Minor (Greek culture)	 By IAU and Sky & Telescope magazine, Sinnott & Fienberg	☐
Polaris	Nicknamed the "North Star", the motionless star, very close to the NCP,	Located at the end of the handle, in the Little Dipper	☑
CASSIOPEIA	Greek - Queen	 By IAU and Sky & Telescope magazine, Sinnott & Fienberg	☐
CEPHEUS	Greek - King	 By IAU and Sky & Telescope magazine, Sinnott & Fienberg	☐

DRACO	Greek - Dragon	 By IAU and Sky & Telescope magazine, Sinnott & Fienberg	☐
Thuban	Greek – star in Draco	Located at the 3rd star from the end of the dragon-Draco's tail	☐

Below is a Data Table (Table 2) of the distance between Polaris and the North Celestial Pole (NCP) over ~130 years. Upon close examination, Polaris, the North Star, is not exactly at the 'motionless' point, the North Celestial Pole (NCP), but is within 1°.

We use 'angular measure' in astronomy to measure distances between two objects in the sky. The entire circle of the sky is 360°. A fist held at arm's length is 10°. The separation from the horizon to the overhead, zenith is 90°. Each degree is 60 arc min ('). Each arc min (') is 60 arc sec (").

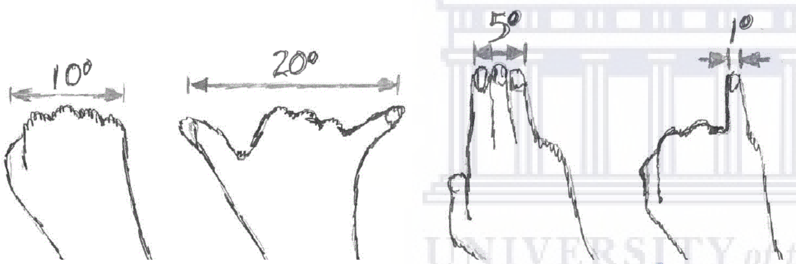


Figure 5- Angular distance, Guy vandegrift, https://en.wikipedia.org/wiki/Angular_diameter

Study the data below. Analyze the pattern of motion. Data points are every ten years, except for the #1.

Table 50- Observational Data of Polaris and the North Celestial Pole (NCP), Zoom (5° x 4°), Source: Starry Nights 6.0 software

Obs.#	**Year**	**Angular separation between Polaris and NCP** (deg˚ min' sec'')	**Comments**
1.	2018	0° 39' 59"	(present year)
2.	2020	0° 39' 24"	
3.	2030	0° 36' 33"	
4..	2040	0° 34' 48"	
5.	2050	0° 32' 37"	
6.	2060	0° 30' 32"	

7.	2070	0° 29' 50"	
8.	2080	0° 28' 28"	
9.	2090	0° 28' 14"	
10.	2100	0° 28' 17"	
11.	2110	0° 27' 23"	
12.	2120	0° 28' 15"	
13.	2130	0° 29' 03"	
14.	2140	0° 30' 38"	
15.	2150	0° 31' 51"	
16.	2160		
17.	2170		
18.	2180		

2. Currently (i.e. this year) what is the angular separation between Polaris and the NCP? _____________

3. Is Polaris currently moving towards or away (-circle one) from the North Celestial Pole (NCP)?

4. Based on the data above, approximately what year will Polaris be closest to the actual NCP?________ ->Indicate "CLOSEST" on the Comments.

5. When Polaris is closest to the NCP, what is the angular separation? _________________

6. Would this data change if we were observing at a different latitude (for example lat. 10 N)? (circle one)

Yes, it the data would change for a different latitude
OR
No, the data would not change for a different latitude

7. Would this data change if we were observing at a different time (for example sunrise in winter)? (circle one)

Yes, it the data would change for a different time
OR
No, the data would not change for a different time

8. ->Fill in rows 16, 17, 18, by predicting the angular separation for years 2160, 2170, 2180. Follow the pattern.

One coordinate system for locating sky objects uses ***celestial coordinates***, the ***right ascension*** (RA) and the ***declination*** (dec.). Right ascension is very similar to the longitude lines of Earth, they run up-and-down like the lines on a beachball. Declination lines are much like lines of latitude on Earth, like the rungs on a ladder. They are located north and south of the celestial equator (Fig. 6 & 7) RA is measure in hours; min; sec. Dec. is measured in degrees; arcmin; arcsec.

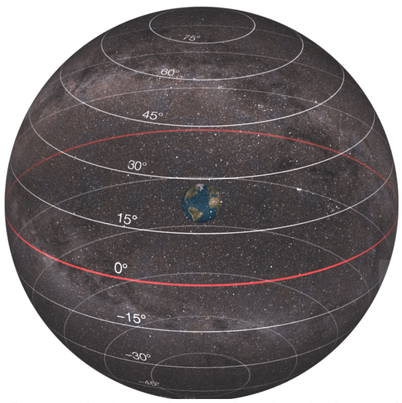


Figure 6 - Declination lines on the celestial sphere, C. Ready 2017

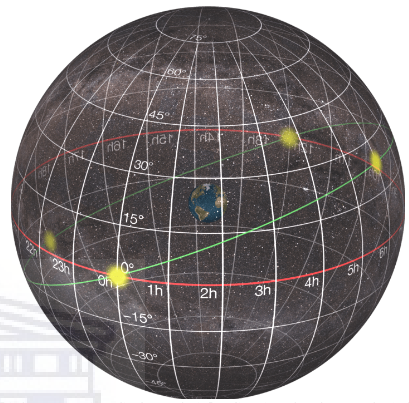


Figure 7 – Right ascension (in hours) & Declination (in degrees), C. Ready 2017

Data Table 3 (below) gives the actual North Celestial Pole, NCP as it changes every two millennia. Study the data. The exact position of the NCP is given in celestial coordinates (RA; Dec.) Use the star map on the last page to complete the following tasks, "SCOO2T CONSTELLATION CHART-NORTH CIRCUMPOLAR REGION-EPOCH 2000".

9. Place a dot on the star map for each data point.
10. Label each data point on the graph with the year.
11. Connect the data points with the best fit curve.
12. Fill in the any remaining rows on the table. Make predictions based on the pattern observed.
13. What shape is this pattern?

Table 51- Actual position of NCP ,Note: We are using 2000 AD as approximately equal to 'present' (2018).

	Years from present:	**Year:**	**NCP position: RA**	**NCP position: Dec.**	**Notes**	**Indicated on Star Map**
1.	0	2000 AD	0h	90°	in Ursa Minor, very near Polaris	☑
2.	2000	4000 AD	23h 5m	79° 0'	in Cepheus	☐

3.	4000	6000 AD	22h 18m	68° 44’	in Cepheus	☐
4.	6000	8000 AD	21h 24m	59° 25’	in Cepheus	☐
5.	8000	10,000 AD	20h 28m	51° 36’	in Cygnus	☐
6.	10,000	12,000 AD	19h 30m	46° 21’	in Cygnus	☐
7.	12,000	14,000 AD	18h 30m	43° 30’	in Lyra	☐
8.	14,000	16,000 AD	17h 30 m	43° 25’	in Hercules, near the bright star Vega	☐
9.	16,000	18,000 AD	16h 30 m	46° 22’	in Hercules	☐
10.	18,000	20,000 AD	15h 32m	51° 46’	in Draco	☐
11.	20,000	22,000 AD			in Draco	☐
12.	22,000	24,000 AD			in Draco	☐
13.	24,000	26,000 AD			in Ursa Minor	☐
14.	26,000=0	28,000AD= 2000 AD			in Ursa Minor	☐

14. Approximately how long is Polaris the ‘North Star”?

15. After the ‘Age of Polaris’, the next Pole Star will be found in the constellation ___________.

16. Approximately how long is one wobble circle or precession circle?
    ____________________years

17. During Egyptian times, 3000BC or 5000 years ago, the star *Thuban* was the ‘North Star’. When will the star *Thuban* in the constellation Draco be the ‘North Star’ again?
    _________AD

18. *** What is causing the wobble? (use an internet search, for example: https://en.wikipedia.org/wiki/Axial_precession)

19. *** How will the seasons on Earth be different than the current seasons when the bright star *Vega* (in the constellation Lyra) is closest to the Pole star?

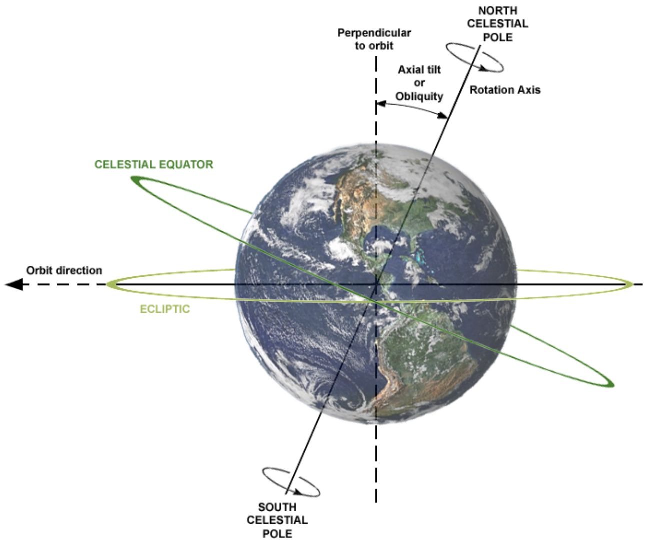


Figure 8- Earth's axial tilt (obliquity) is currently about 23.4°, https://en.wikipedia.org/wiki/Axial_tilt

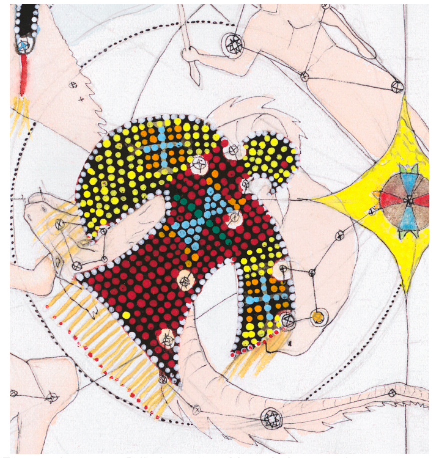


Fig. 9 close up , D/Lakota Star Map, A. Lee et al. 2012

20. Make a sketch of the Thurnderbird, *Wakinyan* constellation on the Star Map, SCOO2T CONSTELLATION CHART-NORTH CIRCUMPOLAR…. See Fig. 9 for reference.

21. Watch the video: https://vimeo.com/309965166. Explain the connection between the motion of the North Star and the Lakota Thunderbird. (i.e. How are: the Earth's 'stable' tilt axis, 'Earth's suitability for life', and the Thunderbird all connected?)

End of Lab.

References and Relevant Links:

https://www.thunderbirdstrike.com/stories/
https://www.thunderbirdstrike.com/stories/

http://web.stcloudstate.edu/aslee/DAKOTAMAP/home.html
https://en.wikipedia.org/wiki/Polaris
https://en.wikipedia.org/wiki/Angular_diameter

https://en.wikipedia.org/wiki/Axial_precession
https://en.wikipedia.org/wiki/Big_Dipper
https://en.wikipedia.org/wiki/Cassiopeia_(constellation)
https://en.wikipedia.org/wiki/Cepheus_(constellation)
https://commons.wikimedia.org/wiki/Category:Celestial_spheres#/media/File:Celestial_Sphere_-_Dec_Parallels_Values.png
https://commons.wikimedia.org/wiki/Category:Celestial_spheres#/media/File:Celestial_Sphere_-_Equatorial_Coordinate_System.png

https://indianapublicmedia.org/amomentofscience/lightening-helps-fertilize-soil/
http://www.roundupweb.com/story/2012/04/04/ag-roundup/lightning-brings-benefits-as-well-as-troubles/301.html
https://www.universetoday.com/19889/did-lightning-and-volcanoes-spark-life-on-earth/
https://science.howstuffworks.com/environmental/green-science/how-forest-fire-benefit-living-things-.htm

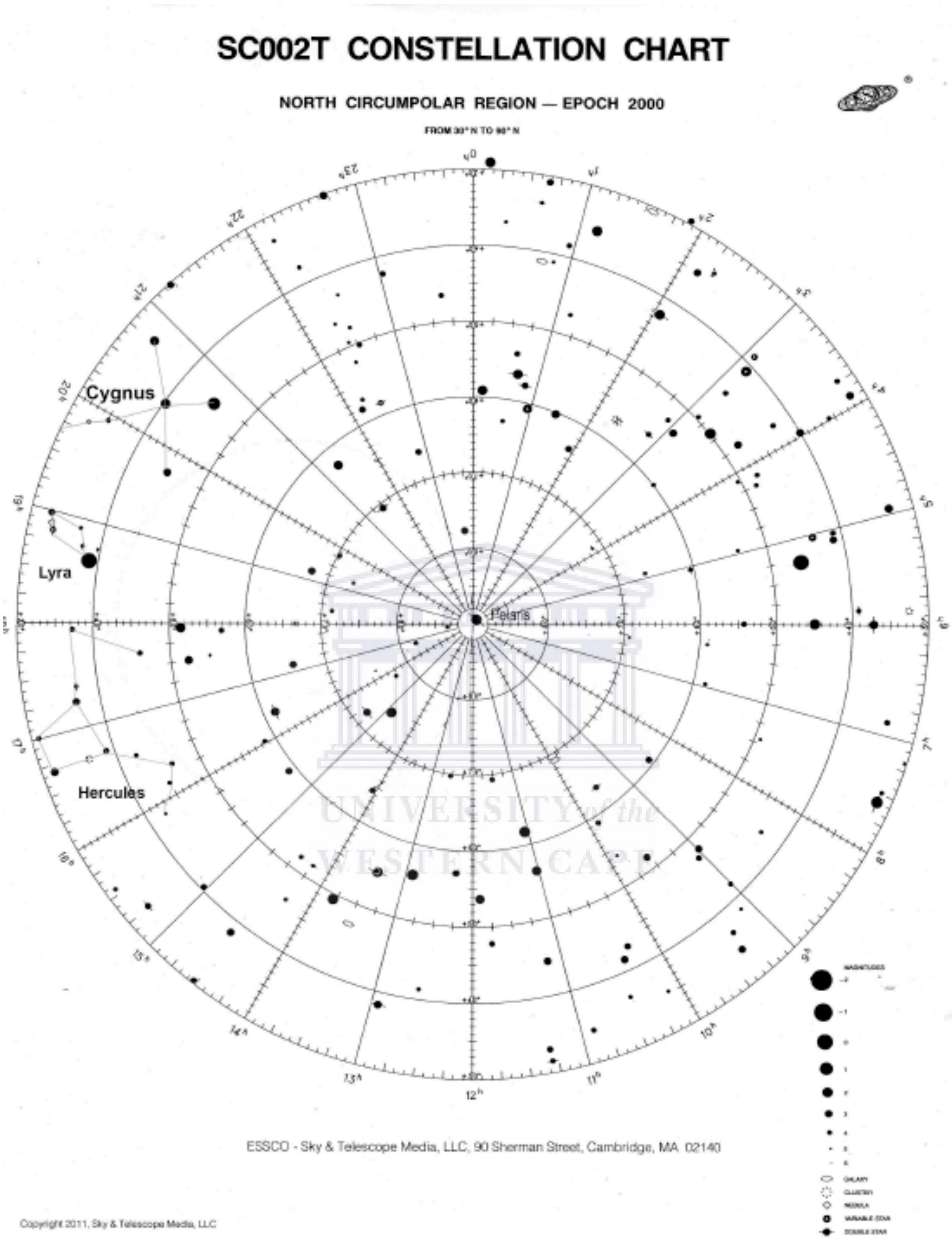


Figure 44- Star map used for 'Motion of the North Star & the Thunderbird' In-Class Activity

End of Lab

In-Class Discussion – *Do you believe in extraterrestrial life?*

Answer the following questions as an **INDIVIDUAL**

Question 1

Do you think that there is life of some form on other planets, or not?

- Yes, there is
- No, there is not
- Not sure

Question 2

Do you think that there is intelligent life on other planets, or not?

- Yes, there is
- No, there is not
- Not sure

Question 3

Do you think that aliens from another planet have ever visited the Earth, or not?

- Yes, they have
- No, they have not
- Not sure

Question 4

Do you think life exists on Mars today?

- Yes, The Red Planet is teeming with tiny microbes, we just haven't found them yet.
- Yes, An advanced civilization lives below the surface, where we can't detect them.
- No – Life never existed on Mars
- No – Mars once had life, but those organisms are long dead.

➔ More on the other side.

Question 5

What is your evidence for your beliefs? Check all that apply and explain.

- ☐ None
- ☐ ALH84001 meteorite
- ☐ Martian face
- ☐ Relative abundance of water
- ☐ Life on Earth thrives in extreme conditions
- ☐ 40 billion estimated Earth like planets in our galaxy
- ☐ Personal experience
- ☐ Other…

Question 6

What kind of reasoning backs your conclusion? Check all that apply and explain.

- ☐ Intuition/Gut Feeling Personal experience
- ☐ Belief system/religious or cultural assumptions
- ☐ Based on facts & logic - Deductive reasoning (For example: All dolphins are mammals, all mammals have kidneys; therefore all dolphins have kidneys.)
- ☐ Based on observations & experience - Inductive reasoning (For example: 100% of biological life forms that we know of depend on liquid water to exist. Therefore, if we discover a new biological life form it will <u>probably</u> depend on liquid water to exist.)
- ☐ The opposite conclusion is absurd – Reductive reasoning (For example: It is absurd to think that human beings are the only life form in the universe.)
- ☐ Other

Other

<u>ASTR 107 - PART 2 – GROUP DISCUSSION (4 people in a group)</u>

1. <u>Assign Roles:</u>

☐ **Scribe** (takes notes on the group's activities) **Name:____________________**

☐ **Proposer** (makes suggestions/explanations to the group) **Name:____________________**

☐ **Skeptic** (points out weaknesses in proposed suggestions/explanations) **Name:________________**

☐ **Moderator** (leads group discussion and makes sure everyone contributes) **Name:_____________**

2. <u>Read this:</u>

In a series for the Discovery Channel the renowned astrophysicist (Stephen Hawking) said it was "perfectly rational" to assume intelligent life exists elsewhere. But he warned that aliens might simply raid Earth for resources, then move on.

> *"If aliens visit us, the outcome would be much as when Columbus landed in America, which didn't turn out well for the Native Americans,"* -Stephen Hawking.

"Prof Hawking thinks that, rather than actively trying to communicate with extra-terrestrials, humans should do everything possible to avoid contact. He explained: "We only have to look at ourselves to see how intelligent life might develop into something we wouldn't want to meet."

In the past, probes have been sent into space with engravings of human beings on board and diagrams showing the location of our planet." http://news.bbc.co.uk/2/hi/uk_news/8642558.stm

> **"The real challenge is to work out what aliens might actually be like"**
>
> Stephen Hawking

Figure 45-NASA image of Stephen Hawking, https://en.wikipedia.org/wiki/Stephen_Hawking

---

☐ TO DO:

3. Take a group vote:
   Should we continue to send out messages to extraterrestrials? Write the results here, and briefly explain.

->More on the other side.

4. Take a group vote:
   Does your group think that if aliens came to Earth, that they would "raid Earth for resources"? Write the results here, and briefly explain.

5. Come up with a Plan for Extraterrestrial First Contact. Make a list of three action items and come to a group consensus in ranking them, highest priority first. Give brief reasons why the ranking makes sense.

CRITICAL THINKING- AT HOME READING & DISCUSSION –

There is no wrong answer.

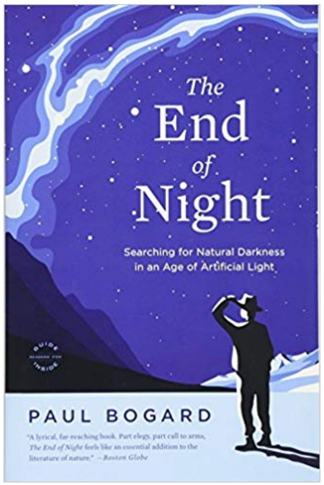
10 pts total =6 Summary of assigned questions + 2 Discussion-Ask an original Question + 2 Discussion-Reply to a classmate's Question

Assigned Reading:

End of Night: Searching for Natural Darkness in an Age of Artificial Light

By Paul Bogard, 2013

Chapter 6 – Body, Sleep, and Dreams



To receive credit for this Reading Activity you must:

- Read the assigned reading above. The scanned chapter is posted on d2l.
- Answer the questions below. Use complete sentences. (typed, double spaced, 12pt font) on the topic. Upload this to the d2l dropbox/assignment folder for this activity.
- Post one question on the Discussion board. Note, discussion will not open until summary is submitted. Think of a thoughtful question. Be specific.
- Respond to at least one other person's question or thread.
- Use .pdf or .doc or .docx formats only for the summary. If we can't open your file it won't be graded and this will result in zero credit.

Due date, see Schedule.

Questions for this reading assignment. Answer in your own words, use three or more complete sentences. Use the internet if more information is needed.

1. Write a brief summary of the problem.
2. Describe possible solutions to this issue.
3. To what extent do you agree with the author?
4. How might cultural, economic, and political differences that affect possible solutions?
5. What is the role of a world citizen, if any, and the responsibility world citizens share for their common global future of 'protecting the dark skies'
6. What are your memories of the stars? Do you have special memories from your youth of seeing the stars in the night sky?

Appendix F – Syllabus, Contract, Schedule

ASTRONOMY 107 – CONCEPTS OF STARS AND THE UNIVERSE

Spring 2019 Section 1

Professor -Annette S. Lee
314 Wick Science Building, WSB
Department of Physics & Astronomy
720 Fourth Avenue
Saint Cloud, MN 56031-4498
aslee@stcloudstate.edu

Course Description: *Concepts of the Stars and the Universe. Scale of the universe; distance, structure and evolution of the stars the Milky Way and other galaxies; cosmology, life in the universe, etc. with emphasis on critical thinking.* 3 Credits

Liberal Education Goals:

- Goal Area 3 –Natural/Physical Science
- Goal Area 2-Critical Reasoning

Course Meeting Times: Wick Science Building (WSB) Room 116
Mondays, Wednesdays & Fridays, 2 – 2:50 pm

Contact Information:
Email: aslee@stcloudstate.edu (preferred)
Phone: 320.308.2013
Office Hours: TBA-see D2L homepage and by appointment as needed.

REQUIRED MATERIALS

Text: *Understanding Our Universe*, 2nd Edition, Palen, Kay, Smith, Blumenthal. ISBN: 13: 978-0393936315. You do not need the access code, Mastering Astronomy, or any other supplement.

Chapters Covered:

Ch 1 - Thinking like an Astronomer
Ch 2 – Patterns in the Sky-Motions of Earth
Ch 3 – Laws of Motion
Ch 4 – Light and Telescopes
Ch 5 – Formation of Stars & Planets
Ch 10 – Measuring the Stars
Ch 11 – Our Star: The Sun
Ch 12 – Evolution of Low-Mass Stars
Ch 13 – Evolution of High-Mass Stars
Ch 14 – Measuring Galaxies
Ch 15 - Our Galaxy: The Milky Way
Ch 16 – Evolution of the Universe
Ch 17 – Formation of Structure
Ch 18 - Life in the Universe

Scientific Calculator: Not an expensive one, but one that can handle scientific notation.

GRADING

TESTS 50%: Four traditional tests will be offered and one Extra Credit Project. Your best three items will be averaged for your grade. The rest are dropped. Tests focus on material after the last test[4]. See Schedule for details. Reviews offered the class before the test day.

AT HOME ASSIGNMENTS 25%: Any activity completed mostly *outside* of class-time, for example Reading Quizzes. Your grade for this category is the average of your best 85% of the items in this section.

IN-CLASS ACTIVITIES 25%: Activities done in class or mostly *in-class*. Your grade for this category is the average of your best 85% of the items in this section.

All dropping happens at the end of the semester.

Letter Grades:

100 –90	A
89 – 80	B
79 – 70	C
69 – 60	D
59 or lower	F

Cheating: Cheating and/or plagiarism will not be tolerated and will be handled in accordance with the St. Cloud State University Conduct Guidelines, which includes failing the course and expulsion.

SCSU Mission:
St. Cloud State University is committed to excellence in teaching, learning, and service, fostering scholarship and enhancing collaborative relationships in a global community.
St. Cloud State University will be a leader in scholarship and education for excellence and opportunity in a global community.

- Will produce an intellectual atmosphere conducive to the comprehensive learning experience by focusing on quality in-class and out of class experiences.
- Will provide meaningful diversity education for the entire campus, including support for curricula that includes diverse perspectives.
- Will use appropriate technologies to enhance teaching, learning, research, creativity, scholarship, and service.
- Will emphasize and support services that lead to higher retention, satisfaction, and success for students, faculty and staff.
- Will serve as a resource for the surrounding community.

Access: Individuals who have any disability, which might affect their ability to perform in this class, are encouraged to inform the instructor at the start of the course. Adaptation of

[4] For the first Test, material covered from the first day of class to the Test Day.

methods, materials or testing may be made as required. For additional information, contact Student Disability Services, sds@stcloudstate.edu, http://www.stcloudstte.edu/sds, 320-308-4080.

Student Learning Outcomes (SLOs):

LEP– Goal 3: **Natural Sciences**

Goal: To improve students' understanding of natural science principles and of the methods of scientific inquiry, i.e., the ways in which scientists investigate natural science phenomena. As a basis for lifelong learning, students need to know the vocabulary of science and to realize that while a set of principles has been developed through the work of previous scientists, ongoing scientific inquiry and new knowledge will bring changes in some of the ways scientists view the world. By studying the problems that engage today's scientists, students learn to appreciate the importance of science in their lives and to understand the value of a scientific perspective. Students should be encouraged to study both the biological and physical sciences.

LEP Objective: Explore scientific knowledge of the natural world. Understand the central concepts and principles of science; experience the process of scientific inquiry; comprehend science as a human endeavor and understand the impact of science on individuals and on society. Students can meet this requirement through 2 approved courses or experiences in different rubrics or academic areas, at least one of these must be a laboratory course.

Students will be able to:

1. Demonstrate understanding of scientific theories.
2. Formulate and test hypotheses by performing laboratory, simulation, or field experiments in at least two of the natural science disciplines. One of these experimental components should develop, in greater depth, students, laboratory experience in the collection of data, its statistical and graphical analysis, and an appreciation of its sources of error and uncertainty.
3. Communicate their experimental findings, analyses, and interpretations both orally and in writing.
4. Evaluate societal issues from a natural science perspective, ask questions about the evidence presented, and make informed judgments about science-related topics and policies.

LEP-Goal 2: Critical Thinking

Goal: To develop thinkers who are able to unify factual, creative, rational, and value sensitive modes of thought. Critical thinking will be taught and used throughout the liberal education curriculum in order to develop students' awareness of their own thinking and problem-solving procedures. To integrate new skills into their customary ways of thinking, students must be actively engaged in practicing thinking skills and applying them to open-ended problems.

LEP Objective: Identify, analyze, and critically evaluate reasoning in a variety of domains in order to develop well founded beliefs and engage in rational and effective action. Students can meet this requirement through 1 approved course or experience.

Students will be able to:

1. Gather factual information and apply it to a given problem in a manner that is relevant, clear, comprehensive, and conscious of possible bias in the information selected.
2. Imagine and seek out a variety of possible goals, assumptions, interpretations, or perspectives which can give alternative meanings or solutions to given situations or problems
3. Analyze the logical connections among the facts, goals, and implicit assumptions relevant to a problem or claim; generate and evaluate implications that follow from them.
4. Recognize and articulate the value assumptions which underlie and affect decisions, interpretations, analyses, and evaluations made by ourselves and others.

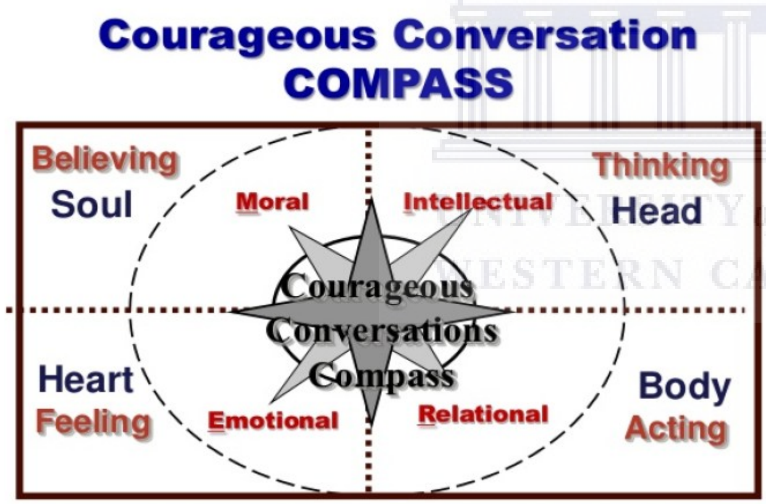
Respect for Pronoun choice: Please feel free to let me know your gender/pronoun preference: she-hers/they-them/he-him.

Gender-Inclusive language guidelines:

Aspiring to create a learning environment in which people of all identities are encouraged to contribute their perspectives to academic discourse, I would like to create an inclusive and welcoming environment.

Language is gender-inclusive and non-sexist when we use words that affirm and respect how people describe, express, and experience their gender. Gender-inclusive/non-sexist language acknowledges people of any gender (e.g. first-year student versus freshman, chair versus chairman, humankind versus mankind). It also affirms non-binary gender identifications, and recognizes the difference between biological sex and gender expression. Students may share their preferred pronouns and names, and these gender identities and gender expressions should be honored.

For Discussions:



Courageous Conversations About Race, Singleton & Linton, 2005

Discussion Guidelines:

- Be respectful
- Speak your truth
- Everyone gets a chance to talk and to listen.

Simple class goals:

- Critical thinking
- Creativity
- Teamwork

Tutoring and Helpful Resources:

- ISELF tutoring – free, for Physics it is in ISELF 332, tutoring is primarily for students in 100- and 200- level courses https://www.stcloudstate.edu/cose/resources/tutoring/default.aspx
- SCSU Academic Learning Center (ALC) – free tutoring in more than 15 subject areas for general education courses, https://www.stcloudstate.edu/alc/tutoring/default.aspx
- SCSU Multicultural Academic Support Center- free 308-5392 https://www.stcloudstate.edu/asc/tutorinfo.aspx
- Student Accessibility Services (SAS) - https://www.stcloudstate.edu/sas/
- Tutor.com - Online tutoring, free 15 hrs. https://www.stcloudstate.edu/online/resources/tutoring.aspx
- Recommended: Free astronomy textbook: https://openstax.org/details/books/astronomy
- Freely downloadable software: https://stellarium.org/

Land Acknowledgement:

St. Cloud State University exists on the traditional and treaty land of the Dakota people, who along with the Ojibwe are the Indigenous peoples of this land, *Mni Sota Makoce* or Minnesota. One big picture goal of this course experience is to advance understanding of the natural world, especially the night sky, in a way that creates a sustainable future for all.

Course Participation Contract

Course: ASTR 107-Section 1
Instructor: Prof. Lee, aslee@stcloudstate.edu

Please read and initial each statement below and upload it to the D2L Dropbox/Assignments folder for this course. The class content will be locked until you submit this contract into the d2l Dropbox/Assignments folder.

_____ I understand this is a 16-week course from 01/14/2019 - 05/06/2019.

_____ I have read the Course Outline and reviewed the Schedule. I agree to be responsible for keeping up with assignment deadlines and completing them on time or before they are due. I recognize this class has strict deadlines for Tests.

_____ I agree to be responsible for keeping up with assignment deadlines and completing them on time or before they are due. I have read the Schedule and recognize this class has strict deadlines that are evenly scattered throughout the semester. Items close at 5 pm on the due date.

_____ I agree to ask questions in person, D2L Discussion page or email if I do not understand the instructions or due dates for an assignment.

_____ I understand that technical problems related to computer connections or equipment cannot be used as an excuse for failure to complete assignments or to participate online. I agree to locate the computer hardware, software, and Internet connections necessary to stay connected and current with my course work online. I am aware of alternate Internet connections available through SCSU's computer labs, other nearby college's library, the public library and any friends, realities or neighbors and will access them if my personal computer equipment is not working.

_____ I understand that technical problems with D2L or continuing studies requires that I contact the technology help desk, Husky Tech, huskytech@stcloudstate.edu, (320-308-7000).

_____ I understand that when material is uploaded to the d2l Dropbox/Assignment folder it must be a single .pdf document with all pages rotated correctly, in numerical order, and located in the correct Dropbox/Assignment folder to receive full credit.

_____ I understand that I am expected to be working a *minimum* of 5 hours/week on this coursework.

_____ In the event that I do not keep up with the course assignments and activities, I understand that I will need to file an official drop request by the date listed on the web site: http://www.stcloudstate.edu/registrar/students/registration/withdrawals.asp.

____I understand that cheating on a test will result in consequences that include: failing the test, failing the class, possible removal from the University.

Print Name: ___________________________ Date:________________

Signature (Ink or electronic ok): _________________________

***** Welcome to Astronomy 107, hope you enjoy this course and let's get started! *****

ASTR 107 – STARS, GALAXIES & THE UNIVERSE –SCHEDULE *** Sp 2019 - 1/14/19 to 5/9/19

Week	Day	Date	In Class:	Deadlines & At home Assignments:
1	Mon	1/14/19	**PART 1– WHERE ARE WE?** Course Outline, Schedule Course Contract to begin	**Read=> Reading Quizzes** Ch. 1 – Thinking Like an Astronomer Ch. 2– Patterns in the Sky Ch. 4 – What is Light
	Wed	1/16/19	Astronomy Education Research (AER) In Class Activity - ADT Assessment Quiz In Class Discussion –Your Connection to the Stars->	At home – Podcast 1 – *Are Dark Skies Going Extinct?*
	Fri	1/18/19	Lecture 1– Where are we – Our Own Backyard (Ch. 1.1, 1.3) -> Extra Practice L1	
2	Mon	1/21/19	No Class- MLK Day	
	Wed	1/23/19	Current Night Sky- *North and Spring Stars* (Ch. 2.1, 1.3)	
	Fri	1/25/19	In Class Activity: *Powers of Ten*	
3	Mon	1/28/19	Lecture 2 – Beyond Pluto & We Come from the Stars (Ch. 1.1-pg. 6, Appendix 1) -> Extra Practice-L2	
	Wed	1/30/19	No Class – Inclement Weather	
	Fri	2/1/19	Lecture 3 – Flavors of Light (Ch. 4-selected sections) -> Extra Practice-L3	
4	Mon	2/4/19	In Class Activity- *Seven Luminaries*	
	Wed	2/6/19	In Class Activity – *Critical Thinking & Case Studies – Part 1*	
	Fri	2/8/19	*** Review for Test ***	
5	**Mon**	**2/11/19**	**TEST 1 in class 2-2:50 pm** **All items from Part 1 due at 5 pm:** **See Checklist.**	
	Wed	2/13/19	**PART 2 – ARE WE ALONE?** In Class Discussion –*Do You Believe in Aliens? Messages to ET?!?*	**Read=> Reading Quizzes** Ch. 3 – Laws of Motion Ch. 5– Search for Planets; Formation of SS Ch. 18 – Life in Universe At home Activity – Podcast 2 – *Artificial Intelligence, Are Robots Taking Our Jobs?!?*
	Fri	2/15/19	In Class Activity: *Kepler's Laws (CAE)* (Ch. 3 selected sections)	
6	Mon	2/18/19	No Class- Presidents Day	
	Wed	2/20/19	Lecture 1– Orbiting (Ch. 3) ->Extra Practice L1 ; Test Return	
	Fri	2/22/19	*Current Night Sky –Fall & Summer Stars* (Ch. 2.1, 2.2, Appendix 4; Ch. 5)	
7	Mon	2/25/19	Lecture 2 –The Search for Exoplanets (Ch. 5; Ch. 7.1) -> Extra Practice -L2	
	Wed	2/27/19	*Current Night Sky – Exoplanets & ET Messages*	
	Fri	3/1/19	In Class Activity – *SETI and the Search for Life*	

	Mon	3/4/19	No Class *** Spring Break Mar 4-8 ***	
	Wed	3/6/19	No Class *** Spring Break Mar 4-8 ***	
	Fri	3/8/19	No Class *** Spring Break Mar 4-8 ***	
8	Mon	3/11/19	Lecture 3 – Life in the Universe? (Ch. 18) ->Extra Practice L3	
	Wed	3/13/19	In Class Activity – *Critical Thinking & Case Studies – Part 2*	
	Fri	3/15/19	*** Review for Test ***	
9	**Mon**	**3/18/19**	**TEST 2 in class 2-2:50 pm** **All items from Part 2 due at 5 pm.** **See Checklist.**	
	Wed	3/20/19	**PART #3- WILL THE SUN BECOME A BLACK HOLE?** Test Extra Credit In Class Discussion – *Space-travel Anyone?* Group Discussion – *Space-travel-#DearMoon*	**<u>At Home: Reading Quizzes</u>** Ch. 10 Measuring Stars Ch. 11 The Sun Ch. 12 Evolution of Low-Mass Stars Ch. 13 Evolution of High Mass Stars
	Fri	3/22/19	In Class Activity - *Motion of the Sun* (Ch. 2)	At home Activity – Podcast 3 – *Space Economy & Who Enforces Space Law*
10	Mon	3/25/19	Lecture 1 –The Active SUN (Ch. 11) -> Extra Practice L1; Test Return	
	Wed	3/27/19	Lecture 2–Spaceweather (Ch. 11, Working it out 11.1- pg. 278) -> Extra Practice L2	
	Fri	3/29/19	Current Night Sky –*Winter Stars* (Ch. 2.1, 2.2, Appendix 4)	
11	Mon	4/1/19	In Class Activity - *Motion of the Moon*	
	Wed	4/3/19	Lecture 3 The Destiny of Stars – low mass/high mass (Ch. 12.1-12.4) -> Extra Practice L3	
	Fri	4/5/19	Current Night Sky –*Top 10 Most Interesting Stars*	
12	Mon	4/8/19	Lecture 4– Black Holes (Ch. 13) -> Extra Practice L4	
	Wed	4/10/19	Current Night Sky – *Night's Brightest Stars*	
	Fri	4/12/19	*** Review for Test	
13	**Mon**	**4/15/19**	**TEST 3 in class 2-2:50 pm** **All items from Part 1 due at 5 pm:** **See Checklist.**	
	Wed	4/17/19	**PART 4 – WHAT IS THE FATE OF THE UNIVERSE?** Discussion Part 4 – *Black Holes, Wormholes, and Parallel Universes; Would You Want to Meet the Other You?!?!*	**<u>Read=> Reading Quizzes</u>** Ch. 14 – Measuring Galaxies Ch. 15 – The Milky Way Galaxy Ch. 16 – Evolution of the Universe Extra Credit Ch. 17 – Formation of Structure
	Fri	4/19/19	Current Night Sky – *Galactic Objects & the Zodiac*	

14	Mon	4/22/19	In Class Activity: ADT Assessment Quiz How to Calculate Your Grade Test 3 Return	At home – Podcast 4 – *Science in Your Life-Would Your Life be Any Different Without Science?!?!?*
	Wed	4/24/19	Lecture 1-Mapping Galaxies (Ch. 14-Measuring Galaxies; Ch. 15 MWG) ->Extra Practice L1	
	Fri	4/26/19	Lecture 2 – Evolving & Merging Galaxies (Ch. 14-Measuring Galaxies; Ch. 15 MWG) -> Extra Practice L2	
15	Mon	4/29/19	Current Night Sky - *North Star forever…?* (Ch. 2-pg. 34) ->Extra Credit Anonymous Class Survey/Quiz (will replace a lower grade)	
	Wed	5/1/19	Lecture 3 – The Big Picture & the Fate (Ch. 16-Evolution of the Universe; Ch. 17-Formation of Structure)-> Extra Practice L3	
	Fri	5/3/19	*** Review for Test	
Finals	**Mon**	**5/6/19**	**TEST 4 same time as class, WSB 116, 1:30-2:30 pm** **All items from Part 4 due at 5 pm** **See Checklist.**	**Extra Credit Project Due**

TESTS –

- Each test will focus on the material covered prior to the test date. All of the Tests are equally weighted & not cumulative. The lowest Test will be dropped. Extra Credit Video Project will replace an additional Test.
- Bring a #2 pencil and a calculator. No other reference materials allowed.
- All due dates, Dropboxes, Discussions, etc. close/end at 5 pm.

Appendix G – NSF Approved STEM fields (3/17/2014)

CHEMISTRY
Chemical Catalysis
Chemical Measurement and Imaging
Chemical Structure, Dynamics, and Mechanism
Chemical Synthesis
Chemical Theory, Models and Computational Methods
Chemistry of Life Processes
Environmental Chemical Systems
Macromolecular, Supramolecular, and Nanochemistry
Sustainable Chemistry
Chemistry, other (specify)

COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE)
Algorithms and Theoretical Foundations
Communication and Information Theory
Computational Science and Engineering
Computer and Information Security
Computer Architecture
Computer Systems, Networking, and Embedded Systems
Databases
Data Mining and Information Retrieval
Graphics and Visualization
Human Computer Interaction
Informatics
Machine Learning
Natural Language Processing
Robotics and Computer Vision
Software Systems and Software Engineering
CISE, other (specify)

ENGINEERING
Aeronautical and Aerospace
Bioengineering
Biomedical
Chemical Engineering
Civil Engineering
Computer Engineering
Electrical and Electronic
Energy

Environmental
Industrial Engineering & Operations Research
Materials
Mechanical
Nuclear
Ocean
Optical Engineering

ENGINEERING (continued)
Polymer
Systems Engineering
Engineering, other (specify)

GEOSCIENCES
Atmospheric Chemistry
Aeronomy
Biogeochemistry
Biological Oceanography
Chemical Oceanography
Climate and Large-Scale Atmospheric Dynamics
Geobiology
Geochemistry
Geodynamics
Geophysics
Glaciology
Hydrology
Magnetospheric Physics
Marine Biology
Marine Geology and Geophysics
Paleoclimate
Paleontology and Paleobiology
Petrology
Physical and Dynamic Meteorology
Physical Oceanography
Sedimentary Geology
Solar Physics
Tectonics
Geosciences, other (specify)

LIFE SCIENCES
Biochemistry
Biophysics
Cell Biology
Developmental Biology

Ecology
Environmental Science
Evolutionary Biology
Genetics
Genomics
Microbiology
Molecular Biology
Neurosciences
Organismal Biology
Physiology

LIFE SCIENCES (continued)
Proteomics
Structural Biology
Systematic Biology
Life Sciences, other (specify)

MATERIALS RESEARCH
Biomaterials
Ceramics
Chemistry of materials
Electronic materials
Materials theory
Metallic materials
Photonic materials
Physics of materials
Polymers
Materials Research, other (specify)

MATHEMATICAL SCIENCES
Algebra, Number Theory, and Combinatorics
Analysis
Applied Mathematics
Biostatistics
Computational and Data-enabled Science
Computational Mathematics
Computational Statistics
Geometric Analysis
Logic or Foundations of Mathematics
Mathematical Biology
Probability
Statistics
Topology

Mathematics, other (specify)

PHYSICS AND ASTRONOMY
Astronomy and Astrophysics
Atomic, Molecular and Optical Physics
Condensed Matter Physics
Nuclear
Particle Physics
Physics of Living Systems
Plasma
Solid State
Theoretical Physics
Physics, Other (specify)

PSYCHOLOGY
Cognitive
Cognitive Neuroscience
Computational Psychology
Developmental
Experimental or Comparative
Industrial/Organizational
Neuropsychology
Perception and Psychophysics
Personality and Individual Differences
Physiological
Psycholinguistics
Quantitative
Social
Psychology, other (specify)

SOCIAL SCIENCES
Archaeology
Biological Anthropology
Cultural Anthropology
Anthropology, other
Communications
Decision Making and Risk analysis
Economics (except Business Administration)
Geography
History and Philosophy of Science
International Relations
Law and Social Science
Linguistics
Linguistic Anthropology

Medical Anthropology
Political Science
Public Policy
Science Policy
Sociology (except Social Work)
Urban and Regional Planning
Social Sciences, other (specify)

STEM EDUCATION AND LEARNING RESEARCH
Engineering Education
Mathematics Education
Science Education
Technology Education
STEM Education and Learning Research, other (specify)