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PROBING SPACE: FORMATIVE ASSESMENT IN A MIDDLE SCHOOL INQUIRY-BASED
SCIENCE CLASSROOM

by

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B.S. Troy University, 2003

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Education
in the School of Teaching, Learning, and Leadership
in the College of Education
at University of Central Florida
Orlando, Florida

Spring Term
2012

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ABSTRACT

This action research thesis was performed to explore the research questions: How did the use of formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?, How did the use of learning scales as formative techniques impact student self-assessment of their knowledge of the Sun-Earth-Moon system?, How did the implementation of formative assessment techniques affect student discourse on the topic of the Sun-Earth-Moon system? Formative assessment techniques including “talk-friendly” probes, sticky bars, and agree-disagree statements were used in the classroom to expose gaps in knowledge, to facilitate discourse, and promote self-assessment. A triangulation of data included a district-provided pre/post-test, teacher observation, written and oral student responses of formative assessment, self-assessment, discourse, and student self-assessment on a learning goal tracker. Data gathered from student responses to formative assessment techniques given during discourse, lab experiences, in written responses, and from the student learning scale tracker were analyzed to expose misconceptions and gaps in knowledge and guide classroom instruction. Data showed that student performance data improved overall and students narrowed gaps in knowledge of the Sun-Earth-Moon system. Improvement in student participation and skill of discourse was evident; however students needed more practice developing written explanations for phenomenon within the Sun-Earth-Moon system. Through the use of self-assessments students showed improvement in ability to self-assess and realized gained knowledge toward their learning goal.

TABLE OF CONTENTS

LIST OF TABLES	ix
LIST OF FIGURES	x
CHAPTER ONE: INTRODUCTION.....	1
Purpose.....	3
Rational	4
Significance of Study.....	6
Assumptions.....	7
Limitations	8
Terms	8
CHAPTER TWO: LITERATURE REVIEW	13
Introduction.....	13
Formative Assessment	14
Inquiry-based science.....	20
Misconceptions	22
Discourse.....	24
Self-Assessment.....	25
Learning Goals.....	27
Conclusion	29
CHAPTER THREE: METHODOLOGY	31
Introduction.....	31
Design of the Study.....	32

Setting	34
Classroom Setting	34
Instruments.....	35
Pre-Post Test	36
Talk-Friendly Probes	37
Self-Assessment Learning Goal Tracker	40
Methods of Data Collection	40
Methods of Data Analysis.....	43
Exit Slips: Agree/Disagree Statements	44
Sticky Bar Questions.....	44
Inquiry-based Lab Activities.....	46
Quantitative Data Analysis	48
Triangulation of Data	49
Summary.....	50
CHAPTER FOUR: DATA ANALYSIS.....	51
Introduction.....	51
A Typical School Day.....	52
Research Question 1: “How did the use of formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?”	53
Research Question 2: “How did the use of learning scales as formative assessment techniques impact student self-assessment of their knowledge of the Sun-Earth-Moon system?	77
Seasons.....	77

Moonlight.....	81
Tides.....	83
Eclipses	84
Student interview	85
Research Question 3: “How did the implementation of formative assessment techniques affect student discourse on the topic of the Sun-Earth-Moon system?”	87
Seasons.....	87
Moonlight.....	89
Tides.....	91
Eclipse.....	92
Student interviews.....	96
CHAPTER FIVE: CONCLUSION.....	98
Introduction.....	98
Limitations	103
Implications.....	104
Final Summary.....	105
APPENDIX A: IRB RESPONSE LETTER	108
APPENDIX B: DISTRICT APPROVAL.....	110
APPENDIX C: PERMISSION EMAIL TO USE KEELEY PROBES	112
APPENDIX D: PARENT ASSENT	114
APPENDIX E: STUDENT CONSENT.....	116

APPENDIX F: SUMMER TALK PROBE	118
APPENDIX G: GAZING AT THE MOON PROBE	120
APPENDIX H: GOING THROUGH A PHASE PROBE.....	122
APPENDIX I: MOONLIGHT PROBE	124
APPENDIX J: LUNAR ECLIPSE PROBE.....	126
APPENDIX K: SOLAR ECLIPSE PROBE	128
APPENDIX L: STUDENT LEARNING SCALE TRACKER	130
APPENDIX M: SEASONS LEARNING GOAL.....	132
APPENDIX N: LUNAR PHASES LEARNING GOAL.....	134
APPENDIX O: TIDES LEARNING GOAL.....	136
APPENDIX P: ECLIPSE LEARNING GOAL	138
APPENDIX Q: LUNAR PHASES AGREE/DISAGREE STATEMENTS	142
APPENDIX R: TIDES AGREE/DISAGREE STATEMENTS	144
APPENDIX S: ECLIPSE AGREE/DISAGREE STATEMENTS	146
APPENDIX T: LEARNING SCALE TRACKER—STUDENT SAMPLE	148
APPENDIX U: STUDENT SELF-ASSESSMENT RESPONSES—SEASONS	150
APPENDIX V: STUDENT SELF-ASSESSMENT RESONSES—LUNAR PHASES.....	152
APPENDIX W: STUDENT SELF-ASSESSMENT RESPONSES—TIDES.....	154

APPENDIX X: STUDENT SELF-ASSESSMENT RESPONSES—ECLIPSES	156
APPENDIX Y: STUDENT SAMPLE RESPONSE—SUMMER TALK PROBE.....	158
APPENDIX Z: STUDENT SAMPLE RESPONSE—MOONLIGHT PROBE	160
APPENDIX AA: STUDENT (ESE) SAMPLE RESPONSE—GAZING AT THE MOON PROBE.....	162
APPENDIX AB: STUDENT SAMPLE RESPONSE—GOING THROUGH A PHASE	164
APPENDIX AC: STUDENT SAMPLE RESPONSE—LUNAR ECLIPSE.....	166
APPENDIX AD: STUDENT SAMPLE RESPONSE—SOLAR ECLIPSE	168
REFERENCES	170

LIST OF TABLES

Table 1: T-Test Analysis of Pre/Post Test 62

LIST OF FIGURES

Figure 1: Agree/Disagree Data--Lunar Phases	60
Figure 2: Agree/Disagree Data--Tides.....	61
Figure 3: Agree/Disagree Data--Eclipses	61
Figure 4: Pre/Post Overall Data based on Gender	65
Figure 5: Pre/Post Standard data based on Gender.....	66
Figure 6: Pre/Post Benchmark data based on Gender.....	67
Figure 7: Pre/Post Overall Data based on Race	68
Figure 8: Pre/Post Standard Data based on Race.....	69
Figure 9: Pre/Post Benchmark Data based on Race.....	70
Figure 10: Pre/Post Overall Data based on ESE and Non-ESE population.....	71
Figure 11: Pre/Post Standard Data based on ESE and Non-ESE population	72
Figure 12: Pre/Post Benchmark Data based on ESE and Non-ESE population	73
Figure 13: Pre/Post Overall Data based on Socio-Economic Status.....	74
Figure 14: Pre/Post Standard Data based on Socio-Economic Status	75
Figure 15: Pre/Post Benchmark Data based on Socio-Economic Status	76
Figure 16: Student Self-Assessment Data--Seasons	81
Figure 17: Student Self-Assessment Data--Lunar Phases	82
Figure 18: Student Self-Assessment Data--Tides	84
Figure 19: Student Self-Assessment Data--Eclipses.....	85

CHAPTER ONE: INTRODUCTION

Formative assessment is an interactive and comprehensive approach that progressively develops confidence and skills of the student in their mastery of learning (WestEd, 2010). In the 2011-2012 school year, I embarked on a new leadership role at a new school as department chair which gave me the opportunity to promote teacher practices to improve student achievement. I believe one such practice is the implementation of formative assessment. This study focused on the use of formative assessment techniques to elicit knowledge and guide student learning. I taught the same subject matter; however, the student population is markedly different than the school I taught at for the previous four years. The student population was different in that there were a higher number of ESE students and a more diverse population. My former school primarily consisted of Hispanic and White students, with some ESE students. The work location where action research took place had a higher population of African-American students and a larger disparity between socio-economic status in the school population. In my classroom, I implemented an inquiry-based approach to science where the textbook is not the curriculum; rather, the Next Generation Sunshine State Standards (NGSS) set forth “Big Ideas” and “Supporting Ideas” to assess student learning. These standards were assessed in the annual high-stakes test known as the Florida Comprehensive Assessment Test (FCAT) in the 2010-2011 school year. I have had experience in teaching this subject matter in a variety of classroom settings ranging from ESOL, honors, advanced, to the standard courses of study. In my experience, I often found that I was working harder than I perceived the students to be working. I would commonly find that students in all stages of learning often put an emphasis on the “right answer” rather than how to think about a topic. This prompted me to examine my practice and

question how to improve my craft. My personal philosophy of education is that one must take responsibility for his learning, and that the teacher is no longer a “provider of knowledge” but a “facilitator of knowledge”. I have found that in order to make this change, I must put student thinking ahead of the recommended order of instruction. It is more important for me to know my students are learning, and thinking about their learning to promote conceptual change than being able to say, “I taught everything I was supposed to teach.”

In preparing for my masters’ thesis, I began to delve deeper into what formative assessment looked like and how to implement assessments. I found the research of Black and Wiliam (1998) to provide a wealth of research in which to facilitate a change in my “habit of mind” in regards to instruction and assessment for learning. In order to strengthen my practice and provide an example of change for my colleagues both at my work location and Professional Learning Community, I used formative assessments to guide my instruction with the goal of measuring the impact on student performance data. When I thought of weaknesses in student learning I often noticed that students struggled to discuss their beliefs if they think their answer is wrong, which ultimately decreases classroom participation. I agree with research that suggests that students can learn more from discourse and assessing their own thinking than from direct teacher instruction (Anderson, K.T. et al., 2006; Black & Wiliam, 1998). Additional aims of my action research thesis were to use formative assessment to strengthen discourse in the classroom culture, improve students’ self-assessment skills, and use student feedback on formative assessments to ask more meaningful questions to enrich student learning.

Purpose

The purpose of this study was to examine the impact that the use of formative assessment has on student academic performance. In addition to analyzing student growth in pre and post-test benchmark data, I wanted to utilize formative techniques to develop student discourse in science through the use of both talk-friendly formative probes and use of formative assessment techniques in learning scales to evaluate student self-assessment of content knowledge. Using quantitative data collected in the study, I wanted to gain a better understanding of what my students' initial thinking was on the topic studied. Through analysis of this data I could provide more tailored instruction to meet their needs. I hoped that the use of formative assessment probes would prompt classroom discourse on the academic topics. I observed and documented how various formative assessment techniques allowed students to assess their learning and have a clear understanding of what they were expected to learn. I hoped to strengthen my practice by using formative assessment techniques and planned on sharing my findings with colleagues to strengthen the quality of teaching in my department.

There were three guiding questions for my action research thesis:

1. "How did the use of formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?"
2. "How did the use of learning scales as formative techniques impact student self-assessment of their knowledge of the Sun-Earth-Moon system?"
3. "How did the implementation of formative assessment techniques affect student discourse on the topic of the Sun-Earth-Moon system?"

Rational

In prior experiences, I had attempted to implement “formative assessments” after attending a workshop by Page Keely and reading about formative assessments and their importance; however, this implementation was not consistent in my instruction. Prior to the start of this study, I researched techniques and approaches that are formative in nature and have improved student learning through their use. My previous experience with formative assessments helped me better understand what the students thought. As I researched more about formative assessment, I realized that the questioning and activities I already implemented were informal formative assessment strategies that allowed me to inventory student background knowledge during, after, or before more formal formative assessments. After implementing formative assessment strategies, I was curious as to what results a more focused action research could produce when coupled with more consistent and rigorous formative assessments.

An opportunity arose for me to become the science department chair and a teacher leader at a new school. Prior to this research, I incorporated technology into my daily instruction to strengthen student communication and self-assessment. I spoke with my principal who informed me that the science department had many young teachers that were in a development stage as it related to implementing strategies to improve student learning. The new work location was not equipped with the technology necessary for daily instruction. My new work assignment included teaching a group of learners with varying levels of abilities and achievement, which caused me to change the direction and focus of my research. As an educator, when I entered a new work location, I also entered a new school culture. It was important for me to assess my student population. Originally, my interest was in student writing and use of technology for collaboration

and communication. My action research focused on my lowest performing classes. Many were ESE and ESOL students. Some students had learning disabilities, while others had behavioral disabilities. All students struggled in writing and explaining their thinking. To focus on students understanding what they already know, I decided formative assessment may be a means to strengthen student self-assessment, discourse and as an educator it would provide me with meaningful insights into student learning. At the same time, the use of formative assessment techniques as well as learning goals to monitor their learning would impact student performance and clarify learning expectations for the student. In addition to a new school location, all teachers in the state were evaluated with a new system that values tracking and monitoring student learning. Through the use of formative assessment techniques, talk-friendly probes, and learning goals I would better serve my students and gain a better understanding of our evaluation system, which is structured based on Marzano's traits of highly effective teachers.

In my seventh period classroom, I had students that, in the past, performed poorly in their academics, many of whom were ESE students. One realization I had while initially working with these students was that many of them struggled with the curriculum because they did not fully understand what they were learning. Many students needed remediation to achieve at the level that they would be assessed. In order to show learning gains and effectively pace my curriculum, I would need to strengthen my ability to understand where the students are and improve their understanding of where they need to be. In my experience, discourse is an integral part of learning and can allow students to recognize their misunderstandings and talk through them to gain a more accurate understanding of what they are learning. My new teaching assignment, in addition to changes in teacher evaluation, and my personal experience in teaching helped me

focus my research on what I as a teacher and my students both needed and deserved the most, a gain in knowledge and a better understanding of the concepts they were expected to acquire.

Significance of Study

This study is an action research into the implementation of formative assessment to assess students' ideas about the Sun-Earth-Moon system. Using formative assessment allows for the learning of subject-specific knowledge and the introduction and development of skills, along with meaningful discussions between students that focuses their learning, and allows for feedback within learning (Orsmond et. al, 2004). I can then use my findings from this action research to add to a growing body of research about formative assessment. This study provided me with the practical experience implementing formative assessments to change and shape student learning. Findings from this study may be used by me to strengthen my practice, as well as serve as a resource for others within this professional learning community.

In 1989, Sadler defined formative assessment as needing three components: a concept of the learning goal, the ability to compare the actual and desired performance, and the ability to close their performance gap. Formative assessment is a process used by the teacher to recognize and respond to student learning to enhance learning during instruction (Cowie and Bell, 1999). Teaching science can pose challenges to teachers. One such challenge is that instruction should be modified *while* learning is taking place. This means teachers must continually assess their students' understanding in order to improve teaching and learning; that is, assessment *for* learning and not *of* learning (Black & Wiliam, 1998; Bell & Cowie, 2001; Black & Harrison, 2001). The science education community is still in the stage of understanding the role of

informal formative assessment in science teaching. By understanding and improving teacher practices involving formative assessment, educators are developing practices related to student learning (Ruiz-Primo & Furtak, 2006). Current research on the topic of formative assessment in science helped shape my research and allowed me to think more reflectively on how to improve my instruction to achieve student success.

Assumptions

Based on a literature review of formative assessment practices in the area of student performance, discourse and self-assessment, I began this study with a few assumptions. My first assumption was that students would have experienced discourse in the science classroom, although some of them may have initial reluctance discussing their views. This could be for a variety of reasons from language barriers to behavior issues, or maybe a lack of confidence or comfort in expressing their ideas. I also assumed the subjects would be able, if not to discuss their ideas, then to write their ideas clearly enough to provide me with a glimpse of what they are thinking. I also assumed that relatively few students would have had experience assessing their learning using formative assessment and would need practice with this task. Entering a new work location, and students not having prior interaction with me, I also assumed it would take some time for students to adjust to an inquiry-focused classroom if they had never experienced that mode of learning before. It can also be assumed that the benchmark tests, from which the students' performance would be measured, pertained to the benchmarks taught within that portion of my curriculum. Furthermore, it is assumed that qualitative data I analyzed were generated and obtained in an objective fashion.

Limitations

The first limitation of this study was the amount of time for data collection. In the curriculum, teachers are allotted four weeks to teach the concepts within the Sun-Earth-Moon system. Research on this topic continued after the winter break, the gap in time between instruction and assessment may have some impacts on student performance. Other limitations to the study was the exchange of students between classes in order to better satisfy class size amendment; however, my classroom was above the mandated size of twenty-two and had twenty-three students, with some student attrition and mobility throughout the study. Some students declined to participate in the study, only allowing for eighteen participants in the study. Having a co-facilitator to provide support to ESE students once a week was also a limitation. During the study, the co-facilitator was often unable to provide support to students due to a medical issue. A new co-teacher was introduced, to the class, it was her first year in a new career field and she lacked an educational background, all her training was on the job site. The co-teachers introduction in the middle of the research may have limited the degree to which accommodations were effectively implemented with students. The data for this study were collected only on the students that acquiesced to the study. Some members of the classroom declined to participate in the study; thus, their responses and scores were not used. In the next section, I provided definitions of terms pertinent to this study.

Terms

Discourse- Classroom or group talk and discussion that allows students to explain

and shape their understanding through talking with peers or the teacher (Anderson et. al, 2007).

Essential Question- A question, rhetorical in nature and a question without a simple answer, a question that deals with the value of the learning goal (Marzano, 2007, p. 179).

Exit Slips— An informal measure of how well students understood a topic or lesson, requiring students to write responses or answer questions at the end of class (Fisher & Frey, 2004)

Formative Assessment- On-going assessment activities that occur during teaching and learning that involves both teacher and student in gather information that can be used to inform instruction and modify learning activities (Bell & Cowie, 2001; Black & Wiliam, 1998).

Formative Assessment Probes- Real-life scenarios, questions or situations that allow students to expose their ideas and talk about or think about science-related phenomenon or concepts. The student is given distracters along with the best answer and are asked to pick the one they agree with the most and explain their choice (Keeley, 2008, p. 102-103).

Formative Assessment Classroom Techniques- Techniques used by the teacher to gather information on student thinking and understanding (Keeley, 2008, p.3-4).

Agree/Disagree Statements—A set of statements that are “fact or fiction” where students are asked to describe their thinking about why they agree, disagree and to describe what they can do to investigate the statements by testing their ideas by

researching what is already known about the topic or using other means of inquiry (Keeley, 2008, p. 48-50).

Annotated Drawings-Students represent their thinking and ideas visually These drawings can be used to encourage student reflection and self/peer assesment to address misconceptions or close conceptual gaps (Keeley, 2008, p.53-55).

Collaborative Clued Corrections-Students work in small groups to gain feedback or revise their thinking and discuss with others their own ideas and modify those ideas without the negative impact of a wrong answer or grade (Keeley, 2008,p.59-61).

Sticky Bars-Students are given a short answer or multiple-choice response. Students record their answer on a sticky note and post it in the classroom as a bar graph, allowing student to recognize the range of ideas about the science topic (Keeley, 2008, p.178-181).

Think-Pair-Share- This gives students an opportunity to engage in and activate their thinking while sharing their ideas with peers and modifying or reconstructing their knowledge after peer interaction and feedback (Keeley, 2008, p. 192-195).

Traffic Cups-This technique traditionally promotes self-assessment and signals to the teacher if help is needed. In this study the cups were modified by adding an additional cup so students could assess their learning on a four-point scale (Clymer & Wiliam, 2006).

Whiteboards-Small group or individual activity used to encourage student idea generation and recording of ideas. Research has found that when students who use this technique are on task, engaged in higher-level thinking, and have more meaningful discourse (Henry, Henry, & Riddoch, 2006).

Inquiry-based Science- Method of teaching science where students learn by doing.

Students develop their own explanations by exploring and engaging in activities that help develop conceptual understanding and science skills (Passmore, et. al, 2009).

Learning Goal- A statement of what students will know or be able to do (Marzano, 2007, p. 17).

Learning Scale- A format similar to a rubric that provides teacher and student with a clear expectation about instructional targets and a description of levels of understanding and performance for those targets. The format used contains whole-point values, zero to four; a score of three is the target as it relates to the learning goal (Marzano, 2007, p19-25).

Misconceptions- Alternative conceptions or ideas about a topic that is unique to the student and not aligned with scientific conceptual reality (Keeley, 2008, p.13-14).

Performance Data- Performance data can ascertain qualitative and quantitative data. Qualitative data that is performance based are assessed notebooks and science labs. For this study, quantitative performance data will be multiple choice district created benchmark exams that test student knowledge of targeted concepts.

Self-Assessment- Practice of students using group, peer, and teacher feedback to evaluate their thinking and their performance within the classroom context (Black & Wiliam, 1998).

In the second chapter, I identified the theoretical and conceptual issues regarding formative assessment. I explored how formative assessment can be impacted or how it can impact student performance, discourse, and self-assessment. The second chapter reviewed

research studies on formative assessment and their implementation. Chapter three included a rational for the research method, define the school and classroom setting, discuss methods, validation and triangulation of data. Data analysis presented in chapter four, identifying themes that emerged from the data collected and my interpretation of the themes. Chapter five summarized the findings of the study, limitations and present implications for future studies.

CHAPTER TWO: LITERATURE REVIEW

Introduction

The focus in U.S. education has been based largely on high-stakes, large-scale assessments in the wake of No Child Left Behind. Pending legislation from the Obama Administration has proposed a plan that could take assessments into a more promising direction. The purpose of this shift is so assessments can provide detailed feedback to teachers to modify their teaching practice and improve student learning (DeBoer, 2011). A critical component of improving teaching and learning is to quickly identify misconceptions so that they do not create difficulties in future learning. The more the education community knows about alternative ideas students have, the better teachers can modify instruction to improve student understanding of science (DeBoer, 2011). Administering assessments that expose misconceptions, along with students' prior knowledge, and current understanding, are essential to educators; however *how* we ascertain that data is an important consideration.

Landmark research, Black and Wiliam (1998) provides the education community with a means to raise standards through assessment. Black and Wiliam found that formative assessment yields higher test scores; however, formative assessment needs to be improved. Some of their findings on how to improve formative assessment was focused on the accuracy of the assessment, feedback given, and student involvement (1998). According to Popham (2008), "Formative assessment can become the catalyst that spurs both teachers and students to routinely make *evidence-based* decision about learning. Such an orientation to teaching and learning will almost certainly improve students' learning" (p. 142). In this chapter, I define formative

assessments, learning goals, explore the views on teaching for conceptual development, and discuss the use of discourse and self-assessment as formative assessments.

Formative Assessment

In this action research, formative assessment drives instruction and is used to foster discourse while student-self assessments allows the teacher to gauge student understanding of learning goal. Formative assessment may also be referred to as assessment for learning. Assessment for learning is the process of interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go, and how best to get there (Assessment Reform Group, 2002). Popham (2008) further defines the process as, “One in which assessment-elicited evidence of students’ status is used by teachers to adjust their ongoing instructional procedures or by students to adjust their current learning tactics” (p. 6). “Formative assessment is part of the instructional process. When incorporated into classroom practice, it provides information on how to adjust teaching and learning while they are happening” (Garrison & Ehringhaus, 2007, p.1).

Formative assessment should include activities that provide feedback to the teacher about the students’ learning or provide feedback to the student about his or her own learning. An assessment activity can help learning if it produces information to be used as feedback by teachers and by students in assessing themselves and each other and for the purpose of modifying the teaching and learning activities in which they are engaged. Such assessment becomes “formative assessment” when the evidence is actually used to adapt teaching work to meet learning needs (Black, Harrison, Lee, Marshall, & Wiliam, 2003). A 2004 study, Wiliam, Lee, Harris, and Black, provided evidence that performance data can be impacted. In the study,

teachers were to implement previously developed formative assessment strategies in their classroom. This study included nineteen single classrooms, four of which were elected for a comparison group study, provides data on performance of twenty-three classrooms. The strategies included questioning, feedback, sharing targets and aims with student, self-assessment, and peer assessment. The researchers were interested in whether a variety of activities used by the teacher presented any structure in terms of frequency of use. Through a cluster-analysis of the variety of assessments, no tendencies of strategies to be used together were found. The teachers chosen in this strategy taught math and science within two pre-selected learning districts at six different schools. In 1999, the teachers attended an in-service training and underwent six months of planning to execute the action plan. Qualitative data were taken from in-service observations and interviews as well as video-taped and observations of formative assessment implementation in the classroom setting. External exams in this study consisted of mandated national and state exams, and school assessments which served as valid instruments to measure student achievement; however, the use of these varied forms of quantitative data collection meant input and output data varied. Researchers accounted for some negative data effects due to the design and complication of the research for the comparative studies. In single classrooms, end quantitative estimate meant an improvement of one-half of mandated national exam per student per study. The researchers conclude if these practices were incorporated, school-wide performance at the school would be in the upper 25th percentile. The extrapolated data suggested that teachers can teach well and receive positive results.

Bell and Cowie simplified Black et al.'s definition stating formative assessment is a "process used by teachers and students to recognize and respond to student learning in order to

enhance that learning during the learning” (2001). In essence, formative assessment is a means of assessment that provides teacher and students with valuable information about where learners are in the learning process. Cowie and Bell (1999) conducted a two year study and developed a model for formative assessment in the science classroom. This study addressed planned and interactive formative assessment and investigated how these types of formative assessment related to learning, as well as the extent to which they depended on teacher pedagogical knowledge. Ten teachers of varied experience participated in this study. The teachers were from two schools, one a girls’ school and the other a coed school. Their research data collection was categorized into three strands: used student and teacher views of assessment, observed actions in the classroom, and teacher professional development in a reflective discourse model. The data were collected through interview, surveys, observation, and video recordings. A total of 65 teacher interviews, 73 student interviews and 128 observations led researchers to refine two models of formative assessment and develop five essential features of formative assessments.

In Cowie and Bell’s planned model, the teacher elicits and interprets assessment information then takes an action with the whole class. “Cycle starts with the student actions, teacher reflecting on what happens, teacher and student develop direction, begin with activity with on-going feedback” (Cowie & Bell, 1999, p.103). The focal point of the planned model was progress in learning a specific science curriculum topic. The teacher would then take a planned activity to gather assessment information. The teacher then used the collected evidence to further elicit evidence of student thinking. Teachers also used data to determine if the students learned what was intended for them to learn in relation to the targeted science topic. One finding of this model was that teachers with more experience were better able to decipher the

formative assessment data for relevant and irrelevant information in student learning. The final step in this model, teachers had to take instructional action on their interpretation of the elicited data. The action taken is the essential part of formative assessment that separates it from summative assessment. It was found teachers acted on assessment data in three different ways: as it pertains to science, student, and care. These are mostly science based. However, it is important to note that the researchers differentiate between the three ways in which teachers acted. Science-referenced actions mediated learning a specific concept; student referenced actions allowed for individual student needs to be met; and care-reference actions pertained to the relationship between students and themselves. Throughout this model of formative assessment it is necessary to note that time taken for the process varied among teachers. The purposes of eliciting planned formative assessment information can be different from the action taken on the information, and students and teachers both contributed to the model in that when the students were taking action, the teacher was eliciting information and vice versa.

In Cowie and Bell (1999) interactive model, takes place during student-teacher interactions. The activity in this model is not planned; rather, it comes about by noticing, recognizing, and responding to individual or small group or whole-class needs. The purpose of the interactive model was to mediate in the learning of individual students in regards to science, social, and personal learning. Ultimately, the purposes emerged based on noticing, recognizing, and responding to student learning and understanding of the concepts. This model allowed teachers to expose misconceptions, or “unacceptable conceptions”, about specific topics. Some teachers delayed learning specific concepts, allowing learning to be student-driven rather than curriculum-driven. This model is limited in the fact that not all student thinking is given to the

teacher. The teacher notices some but not all of student ideas. A key part of the interactive model is noticing, which is different from eliciting in planned information in that verbal and non-verbal cues give information about thinking as well as student written work and actions within activities. The teacher, through interaction, could notice information about some, but not all, students and gather different information from different students at various times. Within the process of noticing, if teachers could recognize what the student meant. The teacher could appreciate the significance of the information observed from the student. The final part of the interactive model, responding, was framed in three categories relating to care, student, and science. Teachers could change their interaction to satisfy student needs. Teachers described this model as an effective use of time, allowing for feedback to be provided to all students, including students with accommodation needs. One caveat listed by the researchers for this model to be effective is that the teacher must be familiar with a variety of assessment strategies and different ways to elicit student responses. This model allowed for focus on the whole student and depended on the teachers' skills of interaction. Relationship with the student and teacher awareness is key in this process. Another aspect of this model is the teachable moment. A teacher must be able to notice and recognize a moment for enrichment or opportunity and respond to it.

One limitation of this model is that only some students are involved at one particular time. In the summary of their study, Cowie and Bell identified five elements of their formative assessment model. The first element in their model emphasised using the two types of assessment (planned and interactive). An elemental feature of formative assessment regarded the complexity and skill associated with the task, which relies on teacher knowledge, must be

presented in an on-going and responsive way, and requires preparation and planning. The purpose for learning has the central role in formative assessment. The teacher's action is to be taken from student responses is a significant element of the model. The final element of their model states data-driven research contributes to the existing body of knowledge on formative assessment. When educators knew about the details of formative assessment it raised teacher awareness and allowed them to reflect on their practice in new ways (p. 114-115).

Sadler first published research on formative assessment in 1989 and emphasized that the pupil must be able to self-monitor and engage in metacognitive activity; they must hold a concept of quality that is similar to the teacher. In order for a student to self-monitor, students must (1) understand the goal or learning objective, (2) compare the current level of performance to the desired level, and (3) engage in action that leads to some closure in the gap between current performance and desired performance. Sadler (1989, p. 120-124) defines formative assessment as, "Formative assessment refers to assessment that is specifically intended to provide feedback on performance to improve and accelerate learning".

For this action research, formative assessments in the form of curriculum-based pre and post-tests as a variety of activities to ensure daily continuous formative assessment can help close the gap between student understanding and desired goals. Bell and Cowie (2001) make a distinction between formative assessments, identifying two types of formative assessment: formal and informal. Information that is gathered and recorded and planned is said to be formal, while informal assessments do not have a written record of information solicited from the learner. The later formative assessment may arise from student responses and can be interactive;

meaning the information that can be gleaned from the informal assessment is interactive between teacher and student during the learning process (Bell & Cowie, 2001).

Assessment that is formative provides a source of data to inform educational decisions that guide instruction day-by-day, minute-by-minute (Leahy, Lyon, Thompson, & Wiliam, 2005). Student responses and ideas can be gathered through formative assessment in the form of assessment probes and classroom techniques, or FACTs (formative assessment classroom techniques). Teachers employ a variety of techniques to obtain and understanding of student learning and modify instruction to fit student and classroom needs. Formative assessment is a continuous process that gathers evidence about how students are progressing toward learning goals. Formative assessment involves students in self-assessment about how their learning progresses, so if students are in charge of their learning and works with the teacher there can be a closure of knowledge gaps between understanding and desired learning. (Keeley, 2008, p. 25-26).

Inquiry-based science

A fundamental characteristic of effective formative assessment is to promote conversations and experiences that allow teachers to *listen to inquiry* (Duschl, 2003, p. 43-45). An additional goal of inquiry-based science and laboratory activities is to provide an experience that is common to each member of the classroom so students know what is being discussed. The teacher must interpret observations of student learning during lab experiences to make a conclusion about student cognition (Coffee, Douglas, & Stearns 2008, p. 147). Ruiz-Primo and

Furtak (2007) relate inquiry activities to formative assessment if they facilitate the *E-R-U Model*, which states:

Formative assessment that facilitates listening to inquiry should include: (1) discussions in which students share or elicit their thinking, ideas and results, (2) allow teachers to recognize student participation and learning, and (3) allow teachers to use students' participation, ideas, and results to develop activities that promote learning (p. 231).

If students are taught science through inquiry, they will *know what they know, how they know what they know, and why they believe what they know* (Duschl, 2003, p. 52). Development of thinking, reasoning, and problem-solving skills to prepare students in the development and evaluation of scientific knowledge, explanations, models, experimental design and questions is a goal of science education reform (Duschl & Gitomer, 1997). The National Research Council (2001) describes the development of these skills as foundational abilities from students to engage in learning science through inquiry. Laboratory investigations have been a staple of science programs since the turn of the 20th century (Hofstein & Lunetta, 2004). Lab investigations are integrated into the science curriculum in a meaningful way to help students develop a deeper understanding of the science content, as well as an understanding of the nature of science, the attitudes of science and the skills of scientific reasoning (Singer, Hilton, & Schweingruber, 2006). Current educational standards emphasize inquiry rather than the memorization of knowledge. Students are encouraged to explore and investigate the world around them. Furthermore, the NRC has indicated that scientific understanding of concepts can be promoted through inquiry when students actively participate in the learning process (NRC, 1996). An

inquiry-based learning experience supports the conceptual understanding of science concepts (Lee & Krapfl, 2002).

Inquiry in science education is focused on the process of developing explanations about the natural world through participation in complex activities of scientific practice. Inquiry is the act of systematically investigating and exploring aspects of the natural world in order to develop coherent explanations for how those features of the world work. If inquiry science instruction is to have any hope of being incorporated into the classroom practices and, more importantly then it is to lead to scientifically literate students who are inspired rather than overwhelmed by science as an intellectual activity (Passmore, et. al., 2009).

Passmore et. al continue to define scientific literacy as “an understanding of the content of science coupled with an understanding of how that knowledge was generated and justified”(2009). In an inquiry classroom, students should be given opportunities to engage in conceptual inquiry as they develop, revise their thinking, and use models, data, or contradictions to achieve conceptual consistency (Passmore, et al., 2009).

Misconceptions

In this action research, the use of formative assessment probes was the predominate means to assess, reveal, and identify commonly-held student ideas. Discussing ideas for assessment probes have the potential to lead teachers to examine their own thinking, sometimes bringing teacher and student misconceptions to the surface (Coffey, Douglas, & Stearns, 2008). A misconception is a view or opinion that is incorrect because it is based on faulty thinking or understanding. Students bring with them their own sets of beliefs and experiences that shape

their understanding. Students are individual learners with individual alternative conceptions or misconceptions. Misconceptions can be corrected, but they must be corrected by their owners. Educators can identify misconceptions by listening, clarifying, analyzing student responses, and by requiring explanations and discussions. (Gooding & Metz, 2010).

In the learning of Earth Science, students have common misconceptions or alternative conceptions regarding this discipline of science. *A Private Universe* (Sadler, Schneps, & Woll, 1987), a documentary which is partly composed of interviews with middle school students, professors, and Harvard graduates about the cause of seasons and moon phases, the researchers found that, regardless of schooling, students hold false beliefs about these concepts. Regardless of education, even Harvard students and faculty revealed misconceptions of the Earth-Moon-System in their explanations. Interestingly, students with much less education offered similar misconceptions. After re-teaching, some students change their conceptions of these concepts, but others held fast to their original misconception. The research demonstrates how difficult it can be to unlearn information. Some researched misconceptions in the discipline of astronomy that students often hold include: (1) the Moon does not rotate on an axis it revolves around the Earth, (2) the phases of the Moon are caused by shadows cast by other objects in the solar system, (3) seasons are caused by the distance from the Sun, (4) alternative concepts of astronomical distances within the solar system, (5) reasons and explanations for tides, and (6) all stars are the same (New York Science Teacher, 2010; Miller & Brewer, 2010; Gooding & Metz, 2010).

Discourse

Black and Wiliam highlight the importance of discussion in their paramount research of formative assessment. Discussion can be used to provide assessment opportunities if the time is taken to look and listen carefully to the talk and actions through which students develop and display their understanding. It is their claim that opportunities for students to express understanding should be designed into teaching and will initiate the interaction through which formative assessment aids learning. Dialogue with the teacher provides an opportunity to the teacher to respond to and reorient the students' thinking. Their research stressed that discourse between students and teachers should be thoughtful, reflective, and focused in order to explore understanding and enacted in a way that gives students and opportunity to think and express their ideas (Black & Wiliam, 1998). Research shows that the role and nature of discourse affects the quality of students' movement within discourse from formative feedback to assessment activities (Anderson et. al, 2007). In the science classroom, a powerful tool of both inquiry and identifying misconceptions is discourse. Some researchers have referred to this activity as discursive practice or argumentation. Discourse is the process by which scientists assess their explanation as they relate to the data or models that were used to develop the explanation (Passmore et. al, 2009). Talk provides a dynamic and interactive platform for scientific exploration and knowledge. Peer and whole-class discussions provide students with opportunities to reflect, disagree, and interrogate scientific claims, along with promoting roles and relationships between past, present, and future understanding (Zack & Graves, 2001).

Self-Assessment

Self-assessment by students is an essential component of formative assessment. When trying to learn, students must understand the desired goal, determine evidence about their present position, and have some understanding of a way to close the gap between the two (Black & Wiliam, 1998). A characteristic of formative assessment is that both the teacher and student are assessing. Student self-assessment is an important part of formative assessment (Bell & Cowie, 2001). Students reflect on their own learning, self-assess, and receive peer feedback (peer-assessment), as well as react to their and others' evaluations of their learning. Formative assessment is not only made up of diagnostic assessments, but also of peer and self-assessment (Chin & Teou, 2009). Providing frequent feedback during the inquiry process helps students develop a deeper conceptual understanding; however, this task can be difficult for the teacher to always provide. One remedy is to use tools such as peers or self-assessment. This feedback has the propensity to give students multidimensional perspectives on work, which leads to an increase in student knowledge. Furthermore, students don't perceive this form of assessment as judgment, but rather as a method for improving their work, resulting in increased understanding by students summarizing their work, discussing their work with others, identifying difficulties, and clarifying complex issues when evaluating their work. Self-assessments are a way to help students clarify their work to date, and allows the teacher to gather information about student perception of progress (Peters, 2008).

In regards to self-assessment, Clymer and Wiliam (2006) conducted a pilot study of a single 8th grade physical science, with a sample population of nineteen students, where teachers

assessed student performance using traffic cups. Students understood that their achievement at the end of the period was more important than at the start, and that the purpose of self-assessment was students were expected to improve in their learning. During the study, students shifted toward goal mastery, where the goal was to understand the concepts. Students learned more when they focused on the concept. The researchers found this practice changed the classroom culture because students were more engaged in monitoring their learning. In this study, it was found that students' ideas of their teacher changed in addition to their own perception of their performance. For example, two-thirds of students saw the teacher as a coach, while one-fifth saw the teacher as a coach and a judge, and only one-tenth saw the teacher as a judge; three-fourths of students thought they performed better in science after self-monitoring practices were put into place. Due to the small sample size, student achievement results of this study were not statistically significant; however, when results were compared to larger sample populations, it was found there was a positive impact on student achievement on assessment for learning (Clymer & Wiliam, 2006-2007, p. 38-42).

Black and Harrison (2001) also conducted a study on the science student's role in formative assessment regarding self- and peer-assessment. In their study, the researchers analyzed the outcomes of twelve science and twelve math teachers at six schools and concluded that an essential condition for the development of formative assessments is that the students are engaged in self- and peer-assessment. During this study, students had to indicate their confidence level in regard to the learning goal. Students colored in a scale of five boxes. Zero or one box indicated the student was confused on the learning goal, while five boxes indicated student confidence in understanding the learning goal. In addition to tracking their learning, the

students added comments to help the teacher analyze student understanding. One difficulty of this approach is actively involving the students, getting them to think about their work in terms of learning goals. This study introduced two new features to teachers. One was peer-assessment of group work and the other, traffic lights. The peer-assessment aspect allowed students to learn from taking the teachers' role and examining the work of others. Value was placed in the work of the student, which allowed the teacher to reflect on what was happening in the classroom and provide interventions to struggling learners. The traffic lights method was a simple means of communication of the students' judgments about their understanding. An advantage of this method was the teacher could, at a glance, identify learning difficulties and target students that needed help without intensive elicitation of student ideas. It was also found that this method allowed for students to communicate their learning to each other. In this study, researchers found teachers valued formative assessment practices as worthwhile and improved day-to-day learning. The employed methods also transferred more responsibility for learning to the student. The teacher role shifted from delivering instruction to coaching student learning, which was a powerful agent of change and allowed for more meaningful feedback to the students, which in turn changed and strengthened the role and relationship between learners and their teachers.

Learning Goals

An important feature of self-assessment within the realm of formative assessment is establishment of learning goals. Assessment *for* learning involves students in their own assessment to gain confidence and achieve at their highest potential. Students, like their teachers, must be engaged in the assessment process (Stiggins & Chappuis, 2006). Research has shown

formative assessment, assessment *for* learning, has shown gains in student achievement, especially among low-achieving students (Black & Wiliam,1998). The problem of students not knowing the purpose of what they are learning and doing makes it hard for students to give meaning to content and apply their learned knowledge. Students want to achieve goals and conceptualize the process toward reaching the goals as a set of instructional activities. Two key components of good science teaching are to provide student with a clear objective and make sure students have the concepts and techniques to achieve that goal (Westbroek, et. al, 2010).

Educators are continually striving to close the achievement gaps of their students. In a 2006 journal article, Stiggins & Chappuis propose that the use of student-involved classroom assessments contributed to positive self-assessment of student thinking. Traditionally, low performers judged themselves as incapable of succeeding. Building on a decade of research allowed Stiggins & Chappuis to build a case for student-involved classroom assessment. The two researchers identified best-practices of teachers that close achievement gaps. Practices included using student record-keeping, involvement in assessment, and communication as a key aspect of continual improvement leading to success in the perspective of the learner. Teachers provided their students with clear and appropriate visions of what they wanted them to achieve, and students kept records to monitor their improvements in performance and conceptual change. Repeated self-assessment allowed the students to watch them grow. By charting their progress, students gained control over their own learning, boosting their confidence (Stiggins & Chappuis, 2006). In their review of research, they set forth conditions for reducing achievement gaps. The first condition was that students need to know what they are expected to learn and what to do to get from where they are to where they should be (Black & Wiliam, 1998; Sadler, 1989).

Assessment *for* learning is a meta-cognitive process in which the student is thinking about themselves as a learner. Assessment must not only be a clear vision, but also one in which the teacher, in assessment *for* learning environments, deconstruct the state standards into classroom targets for students. The clarity of these expectations is of utmost importance in student success in achieving the desired goal. Students must know what they are expected to learn to be actively engaged in the learning process. Student involvement in formative assessment depends on students knowing expectations (Stiggins & Chappuis, 2006).

Conclusion

In this review of literature, cases and arguments have been presented for the effectiveness and use of formative assessment in the accomplishment of student learning goals. A formative means of assessment provides valuable feedback for teachers and use of discourse can become a platform for revealing student misconceptions as well as a means to provide feedback to students during the learning process. The way in which the practitioner tools, such as inquiry-based activities, assessment probes, self-assessment, and learning goals, can impact student performance and mastery of learning goals and objectives. Formative assessment techniques allow the student to think about his learning and understanding. Formative assessment can also convey learning expectations to students. Techniques such as probes, discourse, and self-assessment not only identify misconceptions but help shape the learning environment can be used as a tool to prepare students for summative and high-stakes testing.

In chapter three, I outlined the procedures and design for this action research. The use of formative assessment probes was utilized to facilitate discourse. The uses of learning goals,

deconstructed from state-mandated benchmarks, were used by the teacher to guide instruction and for the student as a means to self-assess on learning expectations. The use of student responses and teacher observations during the implementation of formative assessment techniques provided qualitative data. The use of a pre/post-test served as quantitative data to measure the impact of the use of formative assessment on student performance.

CHAPTER THREE: METHODOLOGY

Introduction

This action research was conducted to implement practices that gave insight into student understanding and learning. The current climate in education places a strong focus on teacher accountability in terms of student performance on high-stakes testing. The purpose of this action research was the use the tool of formative assessments in order to ascertain student ideas about science content before instruction begins. Formative assessment is a tool that teachers can use to guide their instruction based on student needs and student current understanding of topics.

The overarching question guiding this action research project was how effective my teaching practices were on student performance data when I implemented formative assessments. I focused on student ideas in the Earth-Moon-Sun system, which included: reasons for seasons, moon phases, effects of the Sun-Earth-Moon system, and eclipse models. The questions guiding my research were:

1. “How did the use of formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?”
2. “How did the use of learning scales as formative techniques impact student self-assessment of their knowledge of the Sun-Earth-Moon system?”
3. “How did the implementation of formative assessment techniques affect student discourse on the topic of the Sun-Earth-Moon system?”

This chapter described the design of the study, school and classroom setting, instruments, data collected, methods, and data analysis.

Design of the Study

This study was conducted through action research. Action research was chosen because of the nature of the study. Action research taps into the current research base to add to the professional knowledge of practitioners. This form of research was chosen because it involved me, as an educator, to engage in an inquiry process and gain professional expertise that could add to a growing body of research about formative assessment. By its nature, action research creates an opportunity to improve student learning and teacher instruction. The purpose of action research in this study was to empower me as a teacher-leader in inquiry to inform and improve my practice by using results and other research (Katzernmeyer & Moller, 2009, p.56-57). In developing my rationale for using action research I realized that this study would require me to use data to make decisions about the effectiveness of my practice and the techniques used in the classroom to impact student learning.

Formative assessments take on many forms in the classroom. I used a few varieties of formative assessment techniques to probe students' ideas about science concepts. Page Keeley, researcher and teacher leader, has created and published formative assessment probes referred to as "talk-friendly probes". These probes are designed as questions that allow students to select a response they agree with and provide justification for their choice. The probes are written in such a way that they reflect real-world scenarios and focus on science-related concepts. The probes provide choices in which one response reflects the correct thought behind a scientific idea while the other choices are distracters that can expose student misconceptions. These probes allow the classroom teacher and participants to facilitate discourse about the science-related concept

(Keeley et al., 2007, pg. xi). Keeley states, “the probes are not designed for use with control group and comparison studies; rather, they are to serve as a bridge between formal research findings about students’ ideas. The probes are designed for practical application in the classroom. The probes can be used with different state standards and instructional materials because they are based on core science concepts.” (Keeley, et. al, 2005, pg. ix-x). For this study, I utilized the probes to elicit student ideas and promote discourse in the classroom setting and gather data.

In this study, students used learning goals to assess their learning and track their learning on benchmarks that were related to activities within the learning goal. Chappuis and Chappuis (2007/2008), suggested giving a list of student-friendly learning targets as a way for students to build their framework toward the goal. Students were given a tracking chart to both assess and track their learning though the course of the study and related topic, Sun-Earth-Moon system. Students’ periodically evaluated their understanding or performance in the learning goal before and after instruction. For this study, I utilized student tracking as well as observation of student reflections on what they learned. The reflections were in the format of social media posts. The students gave a short summary of what they learned or how their thinking had changed over the course of the learning goal.

To quantitatively measure student learning, I utilized a district-created pre/post benchmark test. This test was designed to provide accountability; therefore, benchmark assessments can be a predictor of future performance. The pre-test was formative in my study because I could use the initial data to target benchmarks with which my students needed the most

help. The test is mandatory in my district, and I used the pre-post test data to measure student performance.

Setting

The study was conducted in an 8th grade Earth Science classroom. The school was located in an urban population of central Florida and is comprised of a student population from different socio-economic communities. In the school, 51.1% of students received free and reduced lunch. The ESE population was 19% and the ELL population was 25.2%. The demographics of the students were as follows: Black, 35.6%; White, 32.2%; Hispanic, 22.8%; Asian/Pacific Islander, 5.7%; Multi-Racial, 3.3%; and American Indian/Alaskan Natives 0.3%. The school used a seven class daily schedule. Every class met for fifty-one minutes four days a week and for forty-one minutes on Wednesdays.

Classroom Setting

A total of twenty-three students were in the classroom. The classroom was comprised of 56.5% males and 43.5% females; 34.7% White, 34.7% Black, 30.6% Hispanic. The classroom had 62.5% of students classified as economically-disadvantaged, receiving free or reduced lunch. Of the classroom population, 45.8% were ESE/Students with Disabilities. According to FCAT data from the 2010-2011 testing year, 37.5% of students scored below Level 3 in Math, and 33% below Level 3 in Reading. Eighteen students agreed to participate in the study and the results of their performance, responses, both written and verbal, as well as teacher observations, were used in the data analysis of this action research. Of the eighteen students that participated in the study

consisted 50% males and 50% females; 33.3% Hispanic, 38.8% Black, 27.9% White; 55.5% were classified as ESE, 72.2% were economically-disadvantaged. The class was my seventh period of the day.

The class also had a support-facilitator, one day a week, to provide ESE accommodations to students. All the students were in 8th grade, and their age ranged from 13 to 15 years. In the seventh period, the majority of the students were classified as ELL (English Language Learner), ESE (Exceptional Student Education). Two of these students were on Behavior Improvement Plans while eleven students had Individual Education Plans. The class also reflected school demographics, more than my other classes. These students were selected because of the diversity of learners in the classroom, and in performance on high-stakes testing these students scored lower than the average performance of students in my other classes. Furthermore, this class was at the end of the day and had a high percentage of low performing students which often were in need of the most attention. This action research allowed me to implement strategies to elicit their ideas and shape my instruction based on student thinking. This classroom was also representative of the classes most of my colleagues had. I felt it important to choose a group that was similar to what fellow teachers encounter in their classroom to become a practical resource for my co-workers. This class would also serve a purpose of action research, an opportunity for collective work and could serve as a model of teacher leadership for my colleagues.

Instruments

This action research required a measurement of student understanding, discourse, and self-assessment of learning goals related to the Sun-Earth-Moon system. The OCPS 8th grade

quarterly benchmark exam was utilized as a pre-and-post-test to provide quantitative data to the teacher researcher to target gaps and weaknesses in student understanding as a pre-test. The instrument used to facilitate discourse was “talk-friendly” probes published by author Page Keeley. All of the probes used received permission from the author before use and the publication of this action research. These probes are two-tiered questions that give students selected responses and require a justification for choice of response. Students choose the statement they agree with most and explain why they agree with their chosen statement. In the probes, one choice is the most scientifically accurate choice while the others are distracters that represent common misconceptions. The probes are aligned with national standards and encompass the state standards covered during this research. These probes are a practitioner’s tool used to engage the students by exposing their initial concepts of the related science topics and allow the facilitator to find out what students are thinking in concurrence with a learning goal (Keeley, 2008).

Pre-Post Test

The post-test served as a measurement tool to determine student learning gains after the implementation of formative assessments. This exam was given Kuder-Richardson 20 reliability of 0.79 after administering the exam to 3630 students in the district I service. The exam tested student knowledge before and after instruction on topics related to the Sun-Earth-Moon system. All instruction was aligned with the state standards and benchmarks. This exam serves as a reliable and valid method of quantitative analysis for student performance.

Talk-Friendly Probes

One of the leading researchers and writers in science formative assessment, Page Keeley, has published several books that contain formative assessment probes to expose student thinking and misconceptions. These probes were embedded into the curriculum and were used for qualitative analysis to understand where students are in their learning process and what gaps existed. For this research, I administered several of these probes that focus on the topic of astronomy. The probes that were used are listed below:

- “Summer Talk”
- “Gazing at the Moon”
- “Going Through A Phase”
- “Moonlight”
- “Lunar Eclipse”
- “Solar Eclipse”

Six formative assessment probes were used in this action research. These probes were chosen because they addressed the standards and encompassed the tasks essential for development of conceptual understanding and depth of knowledge. The standard required students to explain lunar phases and eclipses in terms of the position of the Sun-Earth-Moon system; explain the effect of the Earth’s tilt and position in orbit on Earth’s seasonal changes; and how the position of the Earth-Moon-System impacts tidal phenomenon.

The first probe, “Summer Talk” (APPENDIX E), presented students with the various ideas people may have about why it is warmer in the summer than in the winter. Students described why it is warmer in the summer and explained which statement they agree with the most. This probe elicited students’ thoughts about the change in seasons and the cause of the seasons on Earth. The purpose of this probe is to elicit students’ ideas about seasons. It can be used to determine whether students recognize the effect of the Earth’s tilt on its axis and direct sunlight being the reason for seasons. At the middle school level, students should begin to develop understandings of the Sun-Earth system, including how Earth orbits the Sun and the role of sunlight in heating the Earth. The probe can be used to determine students’ misconceptions about seasons before instruction (Keeley et al., 2008, p. 178).

The second probe, “Moonlight” (APPENDIX: H), required students to explain which statement they agreed with that explains the source of the light from the Moon. Moonlight was designed to expose student ideas of light absorption or reflection being the source of the light of the moon. The purpose of this probe is to expose student ideas about light and the Moon. The probe is designed to determine what students think is the source of a full Moon’s light. In middle school, students begin putting together ideas about the Sun-Earth-Moon system and should be able to distinguish between stars that give off light and planets/moons that can be seen because light reflects off their surface (Keeley et al., 2009, p. 162).

The third probe, “Gazing at the Moon” (APPENDIX: F), asked students how the moon phase may change depending on which hemisphere a person viewed the Moon. This activity was chosen to assess student knowledge of lunar phases and perspective of the Moon from Earth. This probe was designed to gather student ideas about the Sun-Earth-Moon system and to find

out if students think the Moon phase changes based on the observer's location on Earth. This probe may determine if students use the idea of "opposites" in their reasoning about lunar phases seen in opposite hemispheres on the same night. Students in middle school are developing ideas about the geometry involved in the Sun-Earth-Moon system, even though seasons are "opposite" on North and South Hemispheres the lunar phase does not follow the same reasoning (Keeley et al., 2005, p. 178).

The fourth probe, "Going Through a Phase" (APPENDIX: G), presented students with a classroom scenario that lists student ideas about what causes Moon phases. This probe was used before students conducted a lab to simulate lunar phases in order to better tailor instruction to student needs and redirect student thoughts from misconceptions to scientifically accurate statements that describe why lunar phases occur. This probe accounted for student ideas on the cause of the phases of the Moon. Its design is to find out whether students recognize the role of light reflection and position of the Sun-Earth-Moon system to explain why we see different phases. For middle school students, this probe can determine the models students use to explain lunar phases and the probe is used for the purpose of designing instruction to challenge those ideas (Keeley et al., 2005, p. 184).

The fifth and sixth probes provided students with multiple choices for ideas that explain why eclipses occur. The fifth and sixth probes, "Lunar Eclipse" (APPENDIX: I) and "Solar Eclipse" (APPENDIX: J), asked students to choose one idea and justify their response or thinking about the eclipse phenomenon. These probes address the location of the Sun-Earth-Moon bodies during these eclipse events. These assessment probes are designed to expose students' ideas about eclipses and to find out the cause of lunar and solar eclipses. In middle

school, students should be able to compare and contrast lunar and solar eclipses, the use of models is important to develop an understanding of this phenomenon of the Sun-Earth-Moon system (Keeley et al., 2009, p. 169, 177).

Self-Assessment Learning Goal Tracker

In addition to the aforementioned instruments, teacher and department-created learning goals were used school-wide to monitor and track student learning (APPENDIX: K). The learning goals and essential questions were designed to be aligned with the Next Generation Sunshine State Standards and essential questions provided by the district CIA (Curriculum, Instruction, Assessment) blueprint. The essential questions frame instruction as well as served as questions for discussion after the probes were administered. The learning goals (APPENDIX: L-O) are teacher and department-based created goals that describe for students the activities they should be able to complete to perform on target. Students track their assessment of their learning on a teacher created tracking chart. This self-assessment was used to gain insight into student understanding of the learning goal and to determine which students to target for intervention and further instruction.

Methods of Data Collection

The UCF IRB was contacted at the onset of this study to obtain permission to use human subjects for the study (APPENDIX A). The IRB required parental permission; however, formal permission was not needed because the study did not include any procedures that were outside the realm of the regular classroom. The school district was also contacted for permission to

collect data, and permission was granted. All data and student responses were kept confidential and were used only for purposes of the action research thesis and informed teacher instructional practices. In the data analysis, students were provided with pseudonyms to protect the identity of the participants

The collection of data occurred within the second nine weeks of the 2011-2012 school year. In late October, students took the second nine weeks pretest. The Sun-Earth-Moon system was taught from the end of November until the second week in January. Students were administered the post-test January 19, 2012. A T-test analysis was used to measure student performance as demonstrated with questions relating to the Sun-Earth-Moon system. In addition to a T-test that determined significance of data, a means measure test was used to determine the average change in performance on the pre/post-test.

I followed the curriculum set forth by the school district. The students were provided with a formative assessment folder that included the Keeley probes, a learning scale tracker and free-response pages for students to provide additional feedback and reflection on what they were learned. Instruction and data collection was divided into four sections as it pertains to the Sun-Earth System: Seasons, Moonlight and Lunar Phases, Tides, and Eclipses. As students tracked their learning the title of each section was placed above their before and after instruction column on the chart. Through the course of instruction sticky bars were the most frequently used technique. Sticky bars were used to make the students' ideas public before instruction. The data derived from this technique was used to identify the extent to which students had changed their ideas as a result of their learning experiences and interactions in discourse. Before and after

instruction exit slips, in the form of an agree/disagree statement, were also utilized to elicit data from the students.

The typical data collection of each section began with an essential question. The onset of the lesson to be taught began with an assessment probe. The probes were used throughout the research and used to glean information on what students thought and perceived to be true about the Sun-Earth-Moon system. The “talk-friendly” probes were chosen because of the real scenario nature of the probe, as well as its use of illustrations with questions, and space for justification of responses. The lessons using probes were videotaped to analyze teacher questioning and student responses. This provided descriptive data on how formative assessment impacts discourse and how discourse may impact student understanding and self-assessment. Following the administration of the probe, students self-assessed their understanding of the learning goal on their learning scale tracking chart. Formative assessment techniques were also utilized on a daily basis, some of these included but were not limited to: whiteboards, traffic lights, sticky bars, and think-pair-shares. These formative assessment strategies could be used by all populations of students and provided necessary accommodations to ESE students in the classroom. Formative assessments were used to guide instruction, putting the student in the driver’s seat of their education. Teacher observation occurred throughout the research, such as during student work in lab activities, through classroom discourse, by reading the students’ responses to the probes, as well as analyzing self-assessment tracking charts and techniques such as agree/disagree statements. The agree/disagree statements were used on the last three sections as a pre/post exit slip to measure change in student ideas.

Other methods of gathering descriptive data from students included teacher observation, videotaping of lessons, and discourse in the classroom. The videotaping of lessons allowed me to evaluate my reaction to student responses and notice student concepts to shape my instruction. Videotape was transferred to a secure source and erased after completion of action research. On-going informal formative assessment classroom techniques were implemented in order to guide instruction and provide the teacher researcher with feedback of where students were in their learning. This action research explored results of formative assessment classroom techniques while benchmark data will serve as means to measure performance data. All data were collected and analyzed from November to January of the 2011-2012 school year. At the end of the nine weeks a post-test (identical to the pre-test at the beginning of the nine weeks) was given to determine student performance on the related benchmark.

Methods of Data Analysis

The purpose of this study was to identify changes in student understanding of the Sun-Earth-Moon system. Qualitative data on student performance included sticky-bars and agree/disagree statements, talk-friendly probes, and student responses which were analyzed for changes in understanding, including wording and explanations. The classroom discussions were observed and videotaped for further analysis of how the talk-friendly probes affected classroom discourse. The use of learning goals and a tracking chart allowed students to monitor and self-assess their learning and also provided data on student perceived understanding of the learning goal. Students were administered a pre-test at the beginning of the nine-weeks and a post-test at

the end. The pre/post-test provided quantitative data of the students' performance on the overall test, standard, and the benchmark targeted in this study.

Exit Slips: Agree/Disagree Statements

Pre- and post- instruction exit slips (APPENDIX: O-Q), in the form of agree/disagree statements served as a method to determine if student ideas had changed. The pre-post agree/disagree statements also had the learning goal on the bottom to ensure student responses on their learning goal if not noted on the tracking chart. The agree/disagree statements provided a stimuli to encourage scientific argumentation and to help me identify areas that needed targeted instruction.

Sticky Bar Questions

Sticky bars were teacher created questions presented to the students to gauge student understanding of vocabulary and content commonly assessed. The sticky bar technique was used on a frequent basis to make the students' ideas public and identify the extent to which student thinking changed after engaging in learning experiences and interactions during discourse. The sticky bars presented to the students were described below. In this technique, I targeted student ideas of seasons when given an image showing latitude and pole markers indicating the tilt. The pole in the northern hemisphere was pointed toward the Sun and the latitude lines were tilted across the representation of the Earth. In the first question, students were asked to identify the season that would be experienced in the Northern Hemisphere: Winter, Spring, Summer, or Fall. The second question asked students to identify which reason best explains their thinking: (1) The

sun is directly overhead at 23.5 degrees north latitude at this time; (2) The Earth is at vernal equinox, it is March and spring is starting; (3) The Earth is at autumnal equinox, it is September and fall is starting; (4) The sun is directly overhead at 23.5 degrees south latitude at this time.

The third and fourth teacher-created sticky-bar question provided students with a similar diagram except the latitude lines and pole markers were shifted to face away from the Sun in the Northern Hemisphere. In question three, choices included: winter solstice, spring equinox, summer solstice, and fall equinox. The fourth question with the diagram asked students to identify the reason that best explained the change in seasons. Responses students choose from included: (1) Earth is farther away from the Sun when the Northern Hemisphere is experiencing summer; (2) Earth's axis changes the degrees it is tilted during its revolution; (3) Earth's axis tilt changes then angle of direct sunlight the Earth receives; (4) The Southern Hemisphere is closer to the Sun during their summer. The final set of sticky-bar questions had a similar diagram, the pole markers were faced away from the Sun in the Northern Hemisphere, but the lines of latitude were not tilted and went straight across the globe to indicated equal direct sunlight. The fifth question in the series asked the student to identify the month that could be occurring in the diagram: January, December, March, or August. The sixth question asked them to identify the reason that best explained their thinking, choices included: (1) The sun is directly overhead at 23.5 degrees north at this time, it is summer in the Northern Hemisphere; (2) the Earth is at vernal equinox, it is March and spring is starting, Sun's direct rays are hitting the equator; (3) The Earth is at autumnal equinox, it is September and fall is starting, Sun's direct rays are hitting the equator; (4) the sun is directly overhead at 23.5 degrees south at this time, it is winter in the Northern Hemisphere. In probing the conceptual knowledge of tides I presented student with the

following problem. Students were asked to identify the position of the moon during spring tides. On the whiteboard, I drew the Sun to the right, Earth in center, and four moons were shaded to represent the view from space at New, Quarter and Full Moon positions. The Full Moon was labeled as position one, Third Quarter was position two, new moon was position three and First Quarter listed as position four. Students had to indicate the lunar phase during spring tides.

Inquiry-based Lab Activities

Lab activities were also used to probe student understanding, allow students to engage in learning using manipulatives, and teacher observations were made during the labs. These activities were videotaped to review student responses while participating. Two labs were administered regarding Seasons they were Distance Causing Seasons and Modeling Sunlight.

Distance Causing Seasons was to guide student thinking away from distance being a plausible explanation for the change in seasons. In the lab, students were provided with five meters of register tape, metric ruler, and colored pencils. Students were to create a model of the Sun-Earth system when Earth is at perihelion and aphelion (the closest and farthest points in Earth's revolution). After students created the model and determined the difference in distance for aphelion and perihelion, students were provided with an exit slip that required them to fill in the blanks in the following statement: "Sometimes during its' _____ around the Sun, Earth is five million kilometers closer to the Sun. This amount of distance could not possibly be the reason our seasons show big differences in _____ and the length of _____ and _____." The Modeling Sunlight lab, is a teacher led lab to reinforce the idea that the tilt affects the direct sunlight received in a hemisphere thus causing the seasons. This lab

reinforced the standard being taught and dispelled the notion that distance from the Sun determines the season.

The second lab, Modeling Sunlight, was a teacher-led inquiry lab in which students participated and worked together to construct their understanding of why the seasons change. In this lab, one student was selected to model the sun by holding a flashlight, the teacher was the Earth, and the students circled around the Sun and Earth holding constellations, while four students measured the direct “sunlight” and where it was hitting the Earth and all students used data charts to analyze the relationship between latitude and direct sunlight during the four seasons. This lab provided students with an accurate explanation for why seasons occur and was aligned with the standards taught during this action research.

Lunar phases also included a lab where students investigated the position of the Sun-Earth-Moon system and the related lunar phases. Students modeled the lunar phases using a lamp, Styrofoam balls, and recorded observations in their notebooks. Students created a data chart in their notebooks and drew eight boxes that were labeled in degree measurement, starting with zero degrees and ending with three-hundred-fifteen degrees each time increasing by forty-five degrees. After each forty-five degree turn to the left students recorded their observations. After completing this lab, to reinforce vocabulary related to the lunar phases, students were given sixteen plates that represented the moon. Eight of the plates showed half of the moon illuminated, and the other eight represented the moon’s eight phases. In this activity, students worked in groups to create a model of the lunar cycle as viewed from Earth and as viewed from space. Students were also to identify limitations of their model. In addition to creating the model and identifying limitations of models students were also asked to identify the position of the

moon during spring and neap tides. After completing their models, students used Post-It notes to leave feedback for other groups. This lab reinforced the standard which focused on how the position of the Sun-Earth-Moon system accounts for changes in lunar phases and provided students with a hand-on model to explain this phenomenon.

To investigate the effects of the Earth-Sun-Moon system and how it relates to tides, students' graphed tidal data for five different latitude locations along the Eastern coast of the United States. Students were given a lunar chart with dates, and tidal data with corresponding dates. Students worked in small groups to graph the height of the tide and the corresponding lunar phase. This lab activity included the standard that required students to understand how the position of the Sun-Earth-Moon system impacts Earth.

In an investigation related to eclipses, students were to draw a model of a solar and lunar eclipse and identify the parts of a shadow. The problem presented to students was, "What happens during a solar and lunar eclipse? What are the parts of the shadow they form?" Students were provided with a metric ruler, colored pencils, and a hand out with three schematics representing the Sun-Earth-Moon system. Students followed procedures to illustrate the shadows cast during an eclipse. This activity provided students with an understanding of how the position of the Sun-Earth-Moon system can impact eclipses, a phenomenon of the Sun-Earth-Moon system.

Quantitative Data Analysis

The quantitative portion of the data relied on district created pre-and-post exams of the standards and benchmarks. In this study, benchmark SC.8.E.5.9 was analyzed to measure

student performance. The standard reads “Explain the impact of objects in space on each other including: 1. The Sun on the Earth including seasons and gravitational attraction 2. The Moon on the Earth, including phases, tides, and eclipses, and the relative position of each body.” This standard was annually assessed and required a high depth of knowledge. The benchmark was broken down further to ensure students can explain the lunar phase and eclipse phenomena in terms of the relative position of the Sun, Earth, and Moon; explain the lunar tide phenomenon in terms of the relative position of the Sun, Earth, and Moon; and to explain the effect of Earth’s tilt and position in orbit on Earth’s seasonal changes. This breakdown of the benchmark was the foundation of the targeted learning goals students used for self-assessment. After the administration of the second nine weeks post-test, a T-test was used to quantify changes between student performances on the pre-and-post-test data.

Triangulation of Data

The data collected was triangulated for analyses which included student written explanation, and shared explanations during discourse, lab activities, and formative assessment techniques such as sticky bars and agree/disagree statements. In addition to the probes and videotaped discourse, students also monitored their learning using a tracking chart and included a summary statement of their learning. Teacher observations during class discourse, instruction, lab activities, and observations of student tracking and responses to formative assessment techniques were also used in triangulation of data. Finally the use of the pre-post exams provided quantitative feedback on student learning. Using these, data inferences and correlations were drawn about the effectiveness of this practice on student learning. The use of probes,

formative assessment techniques, and self-assessment practices data provided by students allowed me to better target my instruction to students for increased understanding of the Sun-Earth-Moon system.

Summary

In this chapter, I described the design of the study, instruments, and methods of data collection and analysis. A description of the school and classroom setting as well as student population, in which the research was situated, was also discussed. The instruments used for qualitative and quantitative methods and data analysis were also outlined. In Chapter 4, the qualitative and quantitative results of the data from this action research were analyzed for how they related to the guiding research questions: “How does the use of formative assessment impact student performance, self-assessment, and discourse in understanding the Sun-Earth-Moon system?” The next chapter detailed how the action research proceeded and what was found, in terms of themes that emerged, from the implementation of formative assessment techniques and analysis of data to my research group.

CHAPTER FOUR: DATA ANALYSIS

Introduction

This action research study focused on my practice of using formative assessment on student performance, discourse in the classroom, and self-assessment. In this chapter, I analyzed the data collected from teacher observations, formative assessment techniques including talk-friendly probes, annotated drawings, sticky-bars, collaborative-clued responses, agree/disagree statements, student reflections, and performance data from pre-post-test. Student discourse and responses were videotaped and the data provided by students were analyzed. Student data and reflections were collected and analyzed in their formative assessment folders. The folders included all of the probes used in the classroom lessons for the Sun-Earth-Moon system, a tracking chart for student monitoring of learning goals, as well as a section in the folder for reflections to write what they learned related to the science topics we covered. Finally, student pre-and-post test data were analyzed. The data was presented in the order that it was given to the students: *Seasons, Moonlight and Lunar Phases, Tides, and Eclipses*. The results of the formative assessment techniques used as well as discourse were presented in each section. An analysis of the first research question, “How did the use of formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?”, were discussed after the results of the post-assessment at the end of the targeted themes of instruction. Lastly, each question was answered based on triangulation of the data sources. The three guiding questions for my action research thesis were:

1. “How did the use formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?”
2. “How did the use of learning scales as formative techniques impact student self-assessment of their knowledge of the Sun-Earth-Moon system?”
3. “How did the implementation of formative assessment techniques affect student discourse on the topic of the Sun-Earth-Moon system?”

The following section presented an overview of a typical school day and data analysis. I examined the collected data and identified themes and patterns that emerged.

A Typical School Day

A typical school day began with elicitation of data using a formative assessment probe. Students then assessed their understanding of the learning goal on a tracker. The tracker was placed in the students’ formative assessment folder. The tracker included a scale zero to four and students assessed their learning on the scale before and after each lesson. The lessons assessed by students were as follows: *Seasons* (students labeled as orbit and tilt), *Lunar Phases*, *Tides*, and *Eclipses*. Following the probe and initial assessment, students were presented with a variety of formative assessment classroom techniques and inquiry-based lab activities to measure student performance on the standard and benchmark related to the Sun-Earth-Moon system. After analyzing student responses given during discourse, misconceptions were identified and used to develop a more effective means of instruction to target misconceptions and gaps in knowledge. In order to dispel misconceptions and reinforce sound scientific explanations, formative assessment classroom techniques and inquiry-based labs related to the science

concepts that students struggled with were implemented. During the use of formative techniques and lab activities students were encouraged to discuss their findings and develop a deeper understanding of the concepts taught. At the end of the week of instruction on each topic, students indicated their scale score on the learning goal tracker and asked to write how their ideas changed in their assessment folders and share their change in learning during classroom discourse.

Research Question 1: “How did the use of formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?”

To answer this question I used teacher observations from lab activities, data collected from formative assessment classroom techniques, and pre/post test data. After administering the probes, in many cases, it was clear that students lacked conceptual understanding of the cause of seasons. One common response to the probes was for students to copy the response given in the probe and to not provide a separate explanation. Use of formative assessment probes supported that students’ understanding of the Sun-Earth-Moon system varied, had gaps, and science language was problematic for some of them. These factors may hinder their conceptual understanding of the Sun-Earth Moon system.

To develop explanations about concepts related to the Sun-Earth-Moon system a series of probes were used along with inquiry-based labs to assess student performance. During the lab *Does Distance Cause the Seasons?*, four of the six student groups, when questioned, agreed that the difference in the distance during Earth’s orbit would not account for the change in seasons because the difference in aphelion and perihelion were not that great compared to the total

distance from the Sun. These students recognized there are other factors involved in seasons other than distance. However, Julie after participating in the lab, still thought the Earth was closer to the Sun in the summer and farther in the winter. Student explanations of the lab did not reveal adequate content vocabulary to differentiate between climate and weather nor did they show a differentiation between temperature and heat. The use of the probe gave students ideas of possible explanations and the lab expelled the idea for most students that distance is not a cause. Susan wrote after the lab, "I use to think that the seasons changed because of the distance and tilt, but now I know it changes because the tilt." She let go of the notion that the distance from the Sun was a cause for seasonal change. Jamey, had correctly agreed with the probe, "Summer Talk", however his written response, " When we tilt the Sun's rays can hit us a lot more," was evidence that even though the student arrived at the correct answer he lacked the conceptual understanding and science language to explain himself.

The *Modeling Sunlight* activity was used to determine latitudes of most direct sunlight during the Earth's revolution. Four of the students had difficulty understanding what direct sunlight meant even after being shown by the teacher and hearing peer explanations. This was an indication that student performance on science concepts is, to a degree, dependent on students understanding the common language used in science class. Jamey, however, gained a deeper understanding of why seasons changed and shared it with the class. He stated, "The axis did not (change) tilt. It stayed the same, it was the way the Earth moved in its orbit." One of the students that was having difficulty with the data, responded, "Because (of) the tilt (that) means the sunlight hits the Earth more in some locations causing the seasons, when the amount of light changes the season does too." This activity was in response to elicited student responses about

the seasons and the Earth-Sun system in the probe “Summer Talk”. After observing this inquiry-lab I concluded that the use of formative assessments and the impact on student performance on concepts in the Sun-Earth system was foremost an indicator of student conceptual understanding and the results were used to tailor instruction. I was able to target misconceptions, address gaps in content knowledge, and help develop a more accurate science vocabulary for students. I chose to take student feedback to address gaps in knowledge and help students develop explanations for the cause of seasons. I cannot say this strategy worked for all students equally, but knowledge gains were shown in students that participated in the lab exercise and students ability to better explain the reason for the seasons.

The following day, students used annotated drawings, a formative assessment classroom technique, and worked with a partner to draw the motion of the Sun-Earth-Moon system. As I circulated around the room, I noticed many groups were drawing three circles and labeling them Sun, Earth, Moon; however, only one group drew what appeared to be an orbit. I then reminded the students to show how the system moves. I noticed, at that point that most groups were drawing orbits. Groups were then asked to display their annotated drawings. Two groups indicated the direction the Sun, Earth and Moon were moving. One group indicated the orbit of Earth, but no orbit of the Moon around the Earth. Three groups indicated movement of the Earth around the Sun and Moon around the Earth, but did not show the direction of the motion. After students posted their drawings, the class discussed which drawing they thought was most accurate. Jamal stated his group was most accurate because, “the Earth looked like the Earth and not just a circle”. I observed students not focusing on the content; instead they focused on the beauty of the drawing; students were engaged in the activity. It was not until prompting that

students began to indicate orbit and direction or revolution. A benefit of this type of formative assessment was it made student thinking visual and allowed students to peer-assess in order to evaluate ideas. Annotated drawings provided me with an opportunity to explain common language that some students may not use every day. By explaining these terms and how they related to the Sun-Earth-Moon system student performance can be impacted positively. Maggie raised her hand and stated, “The drawing looks good but it does not show that we move counter-clockwise around the Sun and the moon moves counter-clockwise around us.” Abby said she doesn’t understand what counter-clockwise means. Several students raised their hands to explain the idea. Blaine responded, “It means it goes to the left, like a clock going backwards.” The annotated drawings had indicated that students had limited special understanding of the motions in space. Hands-on activities, including the use of manipulatives to reinforce the motion of objects in space were needed to close gaps in knowledge and improve student understanding of the Sun-Earth-Moon system.

In probing student understanding of the Sun-Earth-Moon system, a lab that modeled the lunar phases increased student engagement and provided evidence for explaining the cause of phases. The performance task required students to determine what direction to move to recreate the phase pictured on the projector. Below the picture was the name of the phase. Students were given a Styrofoam ball on a stick and a flashlight was used to represent the Sun. Students worked in pairs, one from the “earthling-view” and another from the “astronaut-view”. Students were engaged in the activity and a few excitedly stated, “I can see it!” referring to the phases of the Moon, “I had to turn counter-clockwise.” One student, Avery, who doesn’t participate in discourse and often seems disengaged in class, came up to me and said, “Depending on where

the Moon is around the Earth I can see the different phases.” The student was then prompted to explain how the light and shadow moves across the surface of the Moon. The students turned around with the manipulative and said, “I see the light going from right to left then the shadow starts moving from right to left after the full Moon.” His partner, Jorge explained, “But from space I always see half of the Moon light up. We only see part of the moon, when we don’t see the moon (New Moon) we just see the dark side. If we see half of it (Quarter Moon) only half of the bright side is showing.” In the student response folder, Brooke wrote, “The phases change based on the position of the Sun, Earth, and Moon,” changing her original idea. This activity revealed that when students were hand-on and minds-on, they were engaged. This activity provided an opportunity for students to develop an explanation that included the position of the Sun-Earth-Moon system as the cause for the changing phases of the moon and to develop an understanding of the motion of objects in space and the interactions of light as viewed from space and Earth.

After the modeling lunar phases lab, students worked together to arrange the lunar phases based on their name to improve science vocabulary among the students. Students worked in groups of two using collaborative clued responses, a formative assessment classroom technique. One student placed the images of the phases under the lunar phase name that was thought to be shown. Then the other student viewed the responses and gave feedback before asking the teacher to check their work. This activity allowed students to work together and facilitated discourse when students disagreed with the image placed by the other student. I paid careful attention to Darrell and Jorge working on this activity. During the modeling of lunar phases, Jorge was eager to share his discovery, but Darrell seemed to struggle with matching the correct phases during

this technique. Jorge worked with Darrell to show him that his shadows were incorrect in the waxing and waning crescent and gibbous phase. I asked Jorge how he knew that Darrell was not correct. Jorge recalled our conversation about the light and shadow movement and pointed out that after the new Moon phase, the light should appear on the right first and Darrell had placed the phase image with the light on the left beside the new Moon phase. Collaborative-clued responses were used twice in the study and in correcting peer writing the technique was unsuccessful, highlighting the struggles many of the students had with writing in the content area. For activities that use manipulatives and schematics, this technique and annotated drawings allowed students to demonstrate their knowledge and clue their classmates in to the correct response. It also was an opportunity for me to notice and respond to gaps in student knowledge and target science vocabulary terms that if a student does not understand, can impact students' performance.

Agree/Disagree statements were also used to measure student performance on concepts in the Sun-Earth-Moon system. Students were provided with an exit slip with agree/disagree statements used formatively to gauge their performance on the understanding of Sun-Earth-Moon system, moonlight, lunar phases, tides and eclipses. The exit slip was given to see if students understood key concepts covered in the probes, labs, and readings and related standard and benchmarks. Common language used by educators and on performance tests is not always common to the student and this language must be taken into account when assessing learners with varying abilities. On the tides exit slip, students were given the statement, "Spring tide only occurs on, March 21st, the vernal equinox in the northern hemisphere and on September 22 in the Southern hemisphere." Eight students disagreed with this statement and seven agreed. When

asked, Jorge indicated he thought the question was asking about when spring occurred. Several students agreed with Jorge. Regarding this concept, the technique was implored after a two-week break so time lapse may have been a factor in student retention. The benefit of the exit slip and the student responding to the exit slip was I was able to change my instruction to review this concept with students.

Sticky bars were used as a formative assessment classroom technique to review the concept of tides. Students were presented with a problem which asked students to identify the position of the moon during spring tides. On the whiteboard, I drew the Sun to the right, Earth in center, and four moons were shaded to represent the view from space at New, Quarter and Full Moon positions. The Full Moon was labeled as position one, Third Quarter was position two, new moon was position three and First Quarter listed as position four. Answer “A” was the correct response stating spring tide would occur at position one and three. Students placed their sticky notes and graphed their answers. Two students chose response “D”, which indicated position one and four, Full and First Quarter respectively, was where spring tides occurred. Seventeen sticky notes were placed under response “A”, which indicated spring tide occurred at positions one and three (Full and New Moon). Maggie raised her and shared with the class how she remembers the arrangement is, a spring tide makes a straight line with the Sun, Earth, and Moon. For clarification, a class a discussion was held to review the position of spring and neap tide. Neap tides occur when the Moon and Sun are perpendicular to the Earth. Sticky bars provided immediate feedback on performance on the question and concept. This technique was a quick and effective way to gauge student understanding of science schematics and language used in questioning and provided a means for discourse in the classroom.

The implementations of pre-post agree/disagree statements revealed student performance understanding the concepts of the learning goal had increased. Student responses to the pre-post agree/disagree format was positive. Abby, Jorge, and Jamal all agreed the exit slips helped them understand what was expected of them and after the content was presented, it was easy to realize where their learning had changed. As the evaluator, I found this technique to be an easy way to target a specific benchmark. The statements were deconstructed from the overarching standard and benchmark taught during this study. Some students held fast to their original ideas, the use of agree/disagree statements provided evidence that a majority of students had changes in their ideas over the course of instruction.

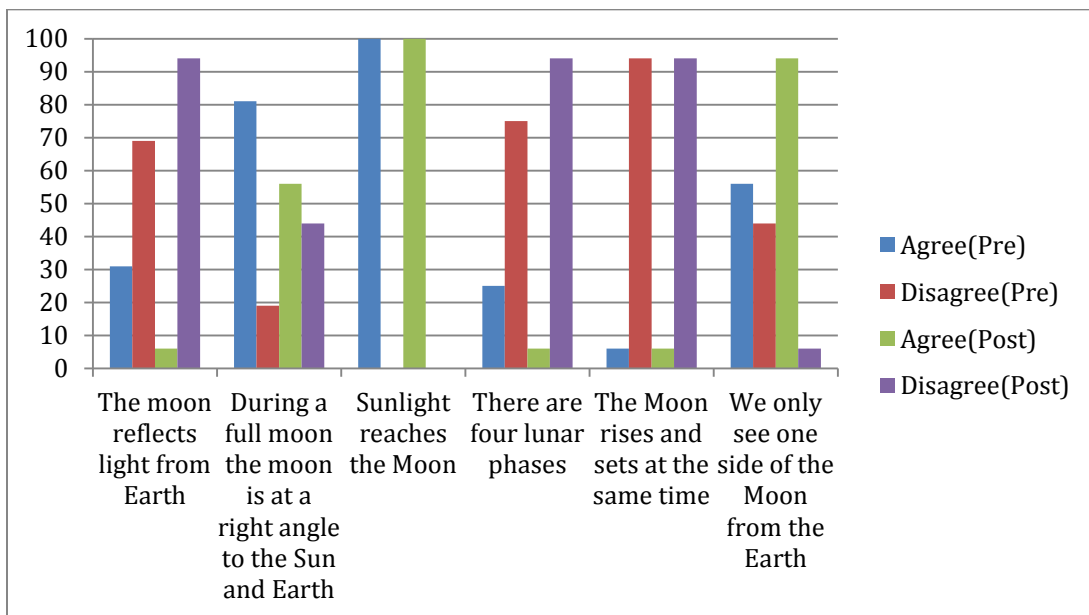


Figure 1: Agree/Disagree Data--Lunar Phases

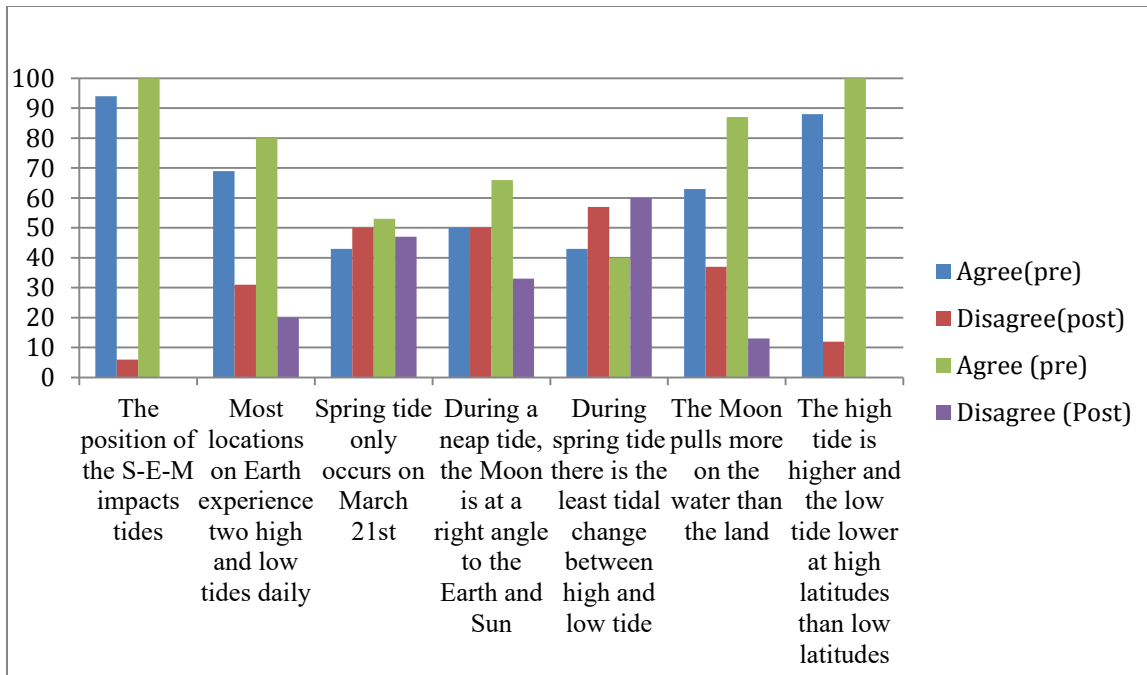


Figure 2: Agree/Disagree Data--Tides

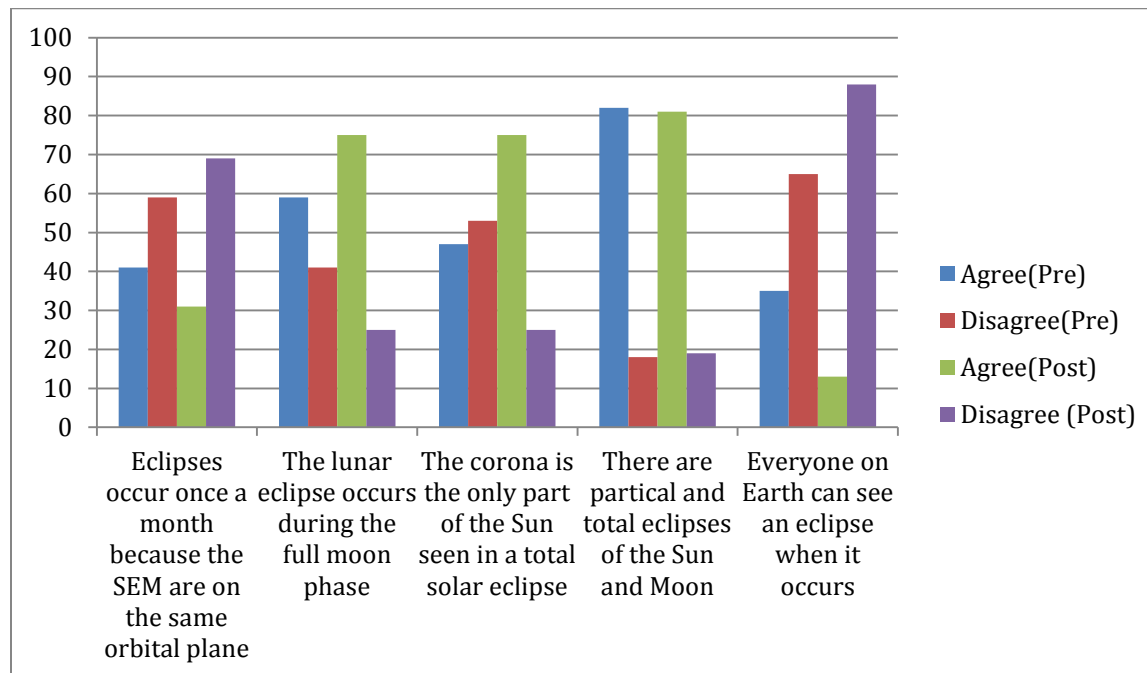


Figure 3: Agree/Disagree Data--Eclipses

The final analysis of student performance was related to the pre/post-test data. A test created by the district included an understanding of astronomy concepts as well as the standard and benchmarks covered over the course of this action research. Several themes emerged after analysis of pre/post performance regarding student attitude and demographics. Student performance between the pre and post-test in all sub groups showed gains in learning, however, in regards to race, white males made a higher gain than white females. Conversely, minority (Hispanic and African-American) females made higher gains than their male counterparts. As a whole, the class performance on the overall test increased, from 38.33% in the pre-test to 60.42% in the post-test. Student performance on the standard and the benchmark taught during this action research increased from pre-test scores. Less than 30% of the questions on the test related to the standard and benchmark; in the post-test analysis of data, students increased to over 50% of the questions correct on both the standard and benchmark. The use of formative assessment techniques and data derived from student responses strengthened my instruction and had a positive impact on student performance.

Table 1: T-Test Analysis of Pre/Post Test

	Number of Questions	Mean Score	Correlation	Significance
Pre Overall	30	11.5		
Post Overall		18.2	.468	.050
Pre Standard	26	9.7		
Post Standard		15.8	.372	.129
Pre Benchmark	9	2.3		
Post Benchmark		4.4	-.004	.987

A t-test indicated a significant change in overall student performance and their performance in the standard tested on the pre and post-test. The assessed data as it related to the benchmark focused on during this study did not yield statistically significant results on the test. A marginal means test was conducted to show variance among subgroups. This analysis took the average performance of subgroups on the pre/post-test to show changes in performance among subgroups. No statistical significance was shown between performance based on race, gender, economic status, and past FCAT performance as it related to the pre-post-test. Of interest, however, was how the pre-post test data related to gender, race, ESE students, and socio-economic status. In the figures below the measured means results show *time* (1) the pre-test and (2) the post-test. Figures 1-3 show, as it related to mean overall performance, standard performance and benchmark performance on the pre/post-test, female student began at a lower overall performance level than their male counterparts but made higher gains in knowledge on the post-test performing at an equal level to their male counterparts. Relating to the standard and benchmark taught (Figures 5-6) female students once again started at a lower performance level and outperformed their male counterparts. The average performance of students, as it related to race, revealed all students made gains in knowledge; however, African-American students consistently performed below their Hispanic and Caucasian counterparts. Two students performed worse on the post-test than pre-test, one an African-American male and the other an African-American female. During a post-test conference it was clear that the male was affected by problems at home and conveyed his mind was not on the test. The female was having social issues at school and also conveyed she just wanted to finish the test and guessed instead of reading the questions. This may partially account for the lower performance; however, a larger

population size may produce more conclusive results. The ESE subgroup analyzed using the estimated marginal means (Figures 10-12) indicated students within the ESE subgroup made gains. The gains made were lower in both overall performance and performance on the standard. As it related to the benchmark, ESE students outperformed, on average, their non-ESE counterparts. This is of interest to the research and how formative assessment impacted this group of students. The use of the chosen formative assessment techniques closed gaps in knowledge and led to the development of conceptual knowledge within this subgroup. The final subgroup, socio-economic status (Figures 13-15), indicated these student on average performed at a lower level on the overall, standard, and benchmark when compared to their peers. However, on average, student in this subgroup did show a gain in performance score on the post-test.

The gain in performance scores indicated that my use of formative assessment techniques clarified the content by helping students understand what schematics in questions are asking and gave students tangible evidence to explain phenomenon in the Sun-Earth-Moon system. Even though the pre-post test data did not indicate a significant change in performance on the benchmark, this could be attributed to the limited number of questions on the exam (nine) that dealt with the benchmark, the standard included twenty-six points and showed statistically significant gain, the overall performance was out of thirty points and was also statistically significant for the overall group but not for sub-groups. The size of the sub-groups and possible points available may have been factors in determining the statistical significance

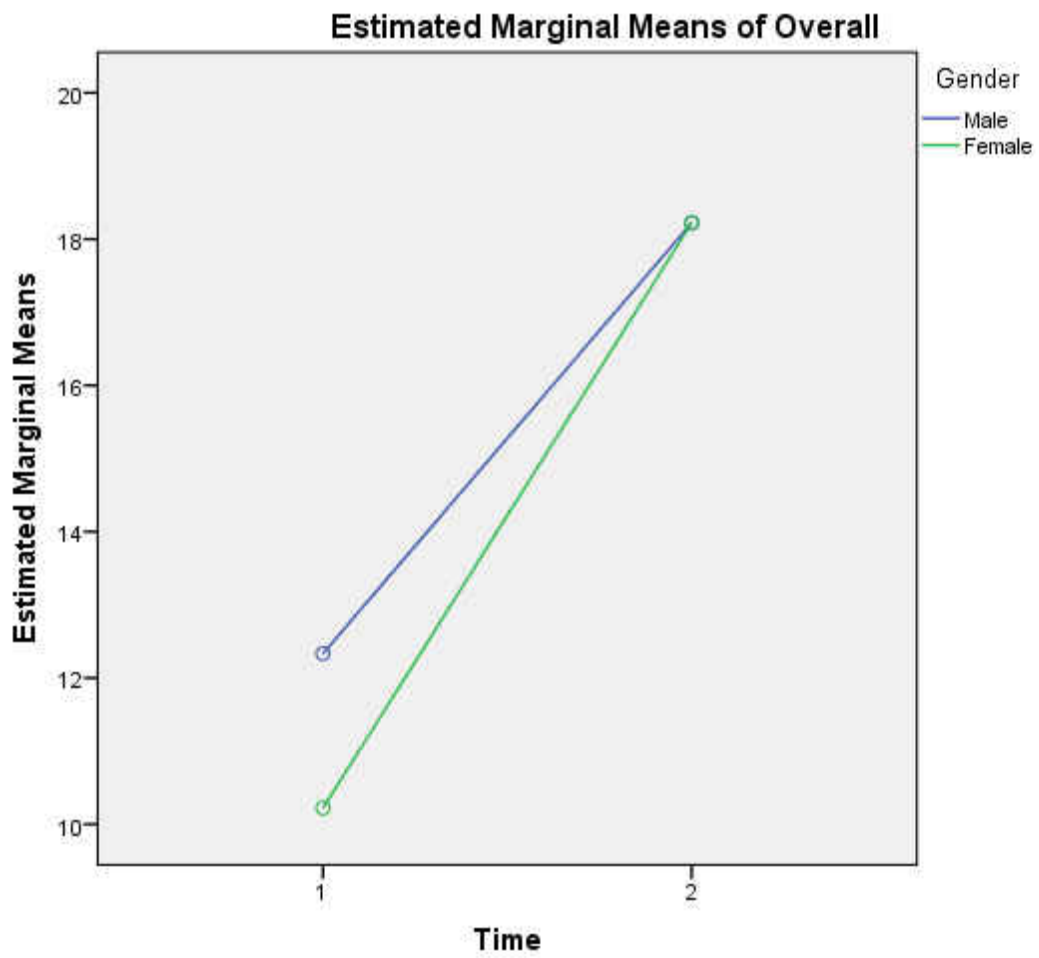


Figure 4: Pre/Post Overall Data based on Gender

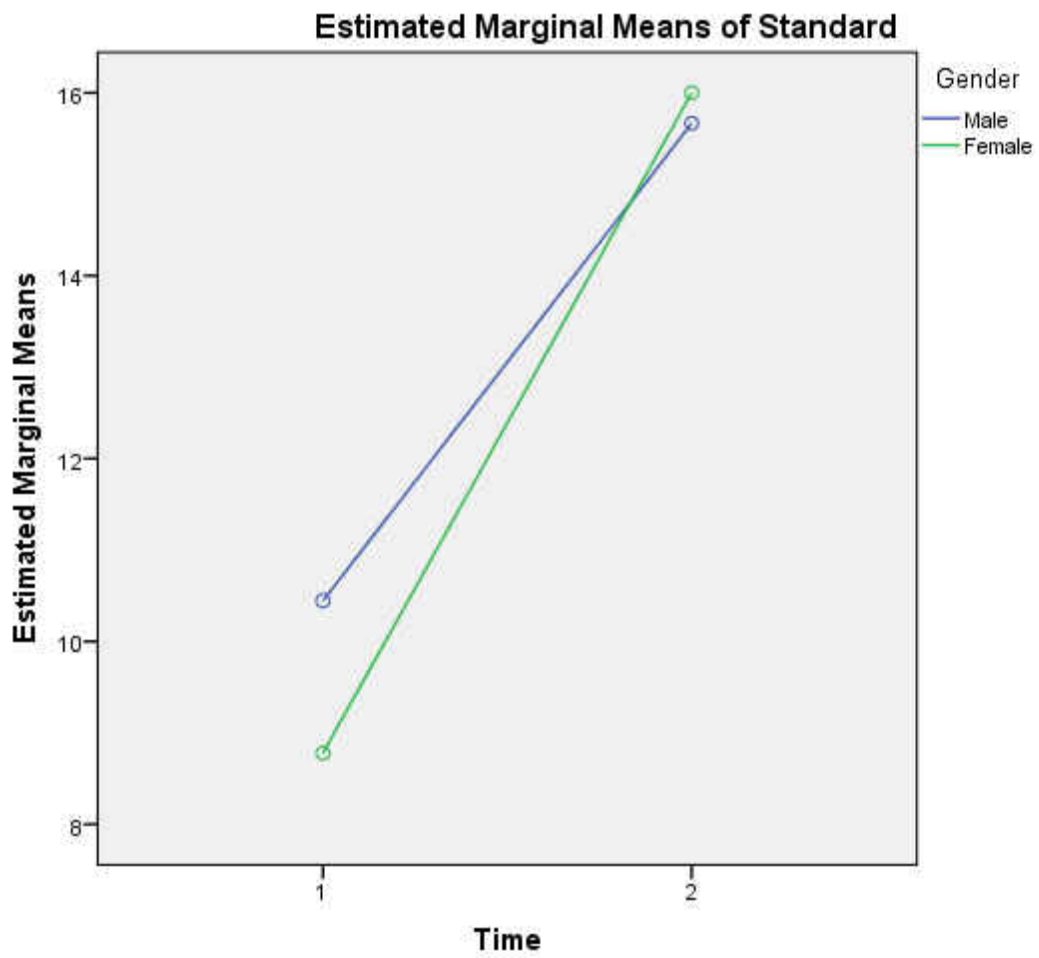


Figure 5: Pre/Post Standard data based on Gender

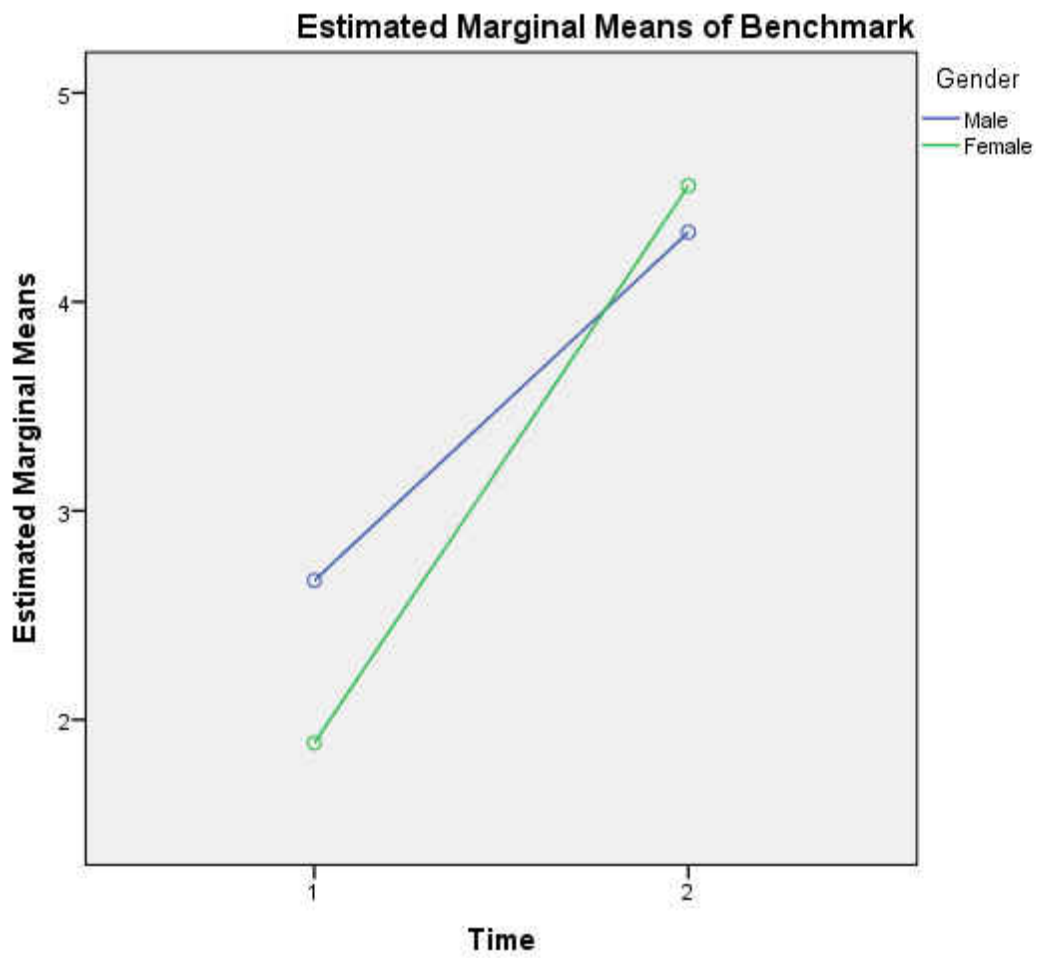


Figure 6: Pre/Post Benchmark data based on Gender

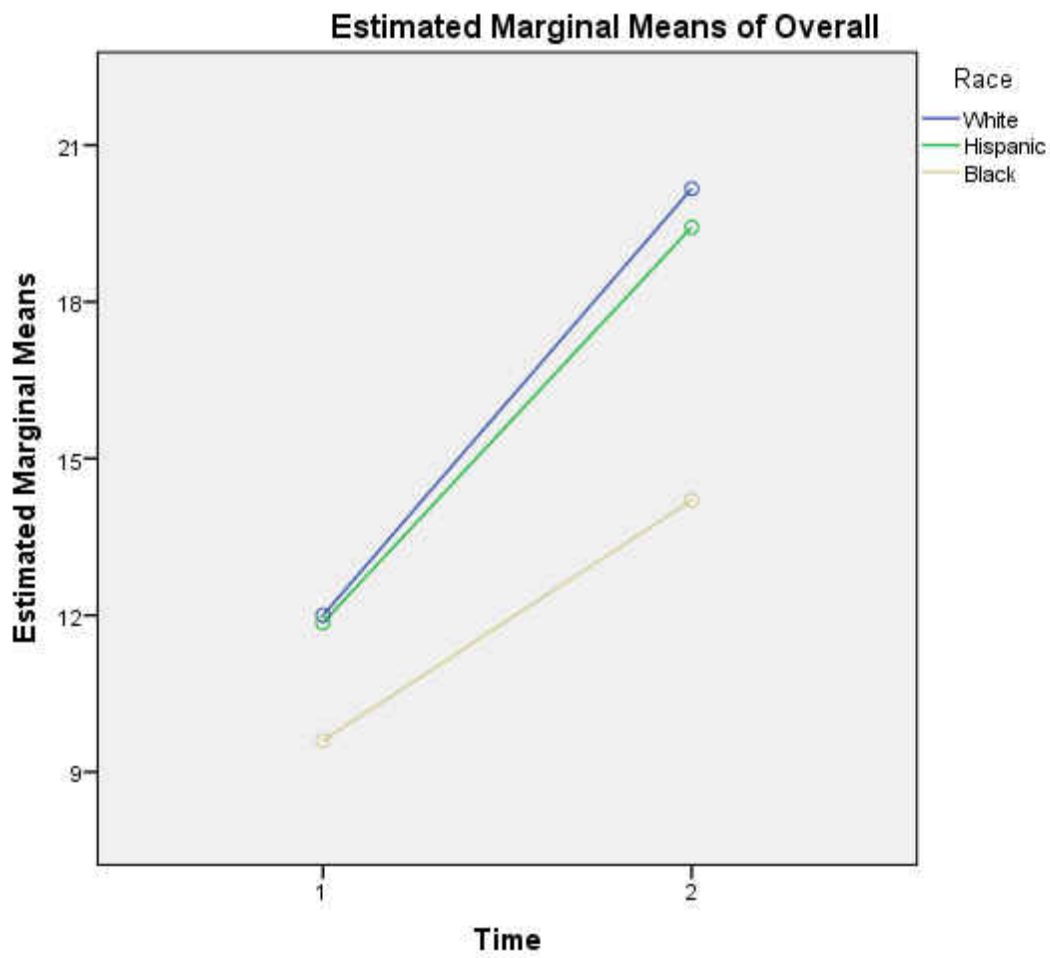


Figure 7: Pre/Post Overall Data based on Race

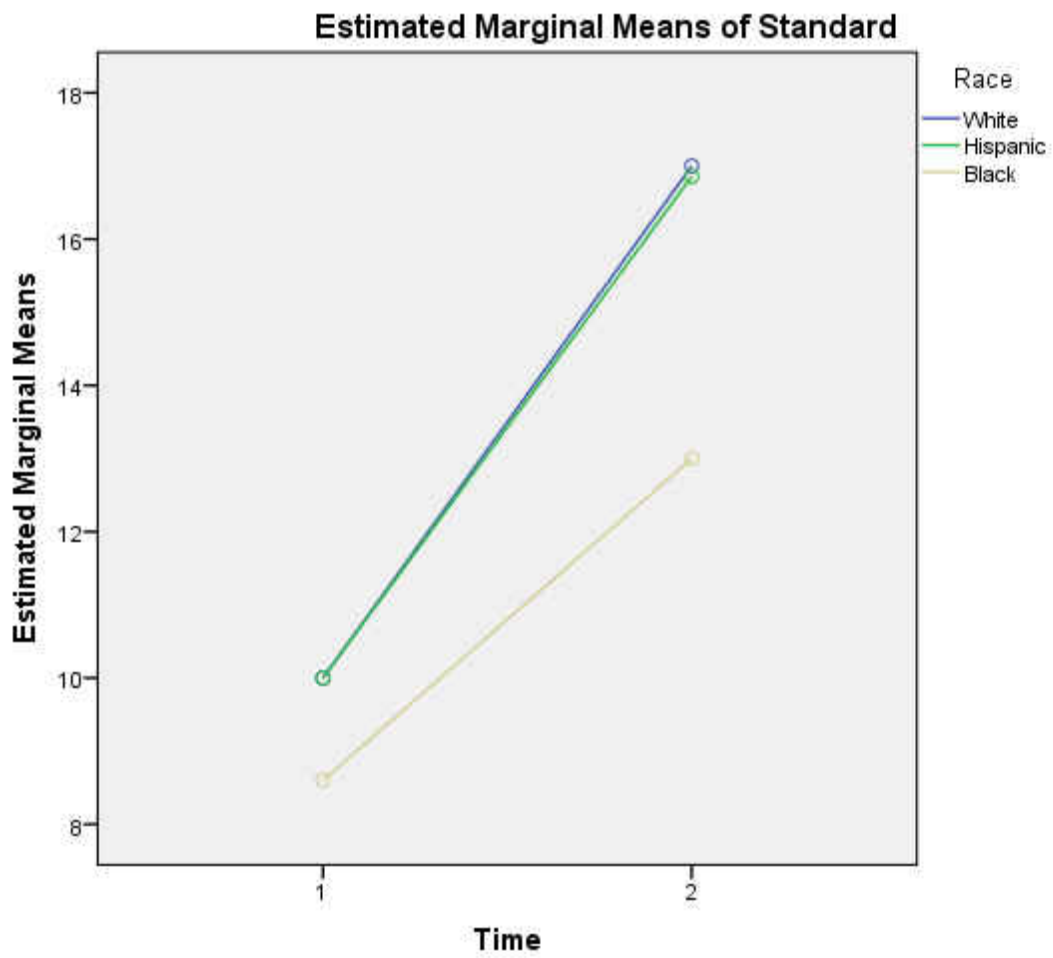


Figure 8: Pre/Post Standard Data based on Race

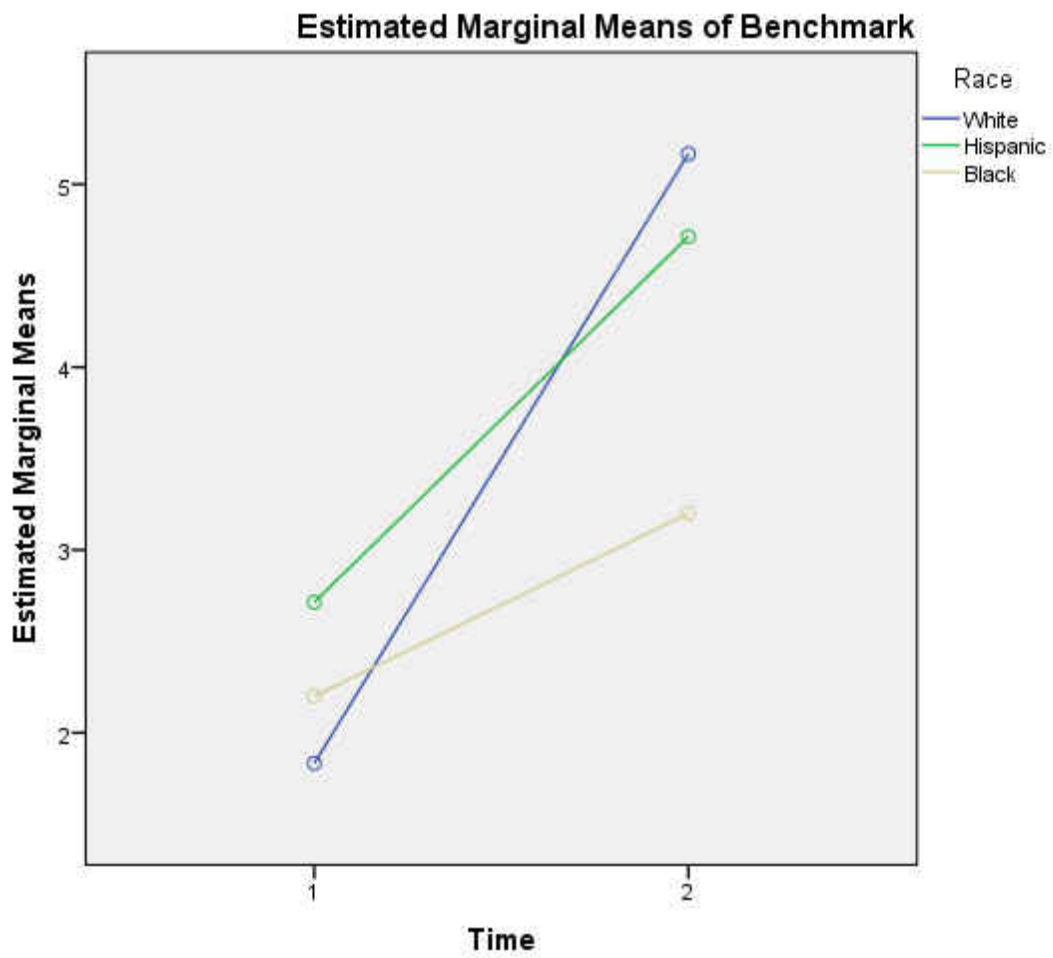


Figure 9: Pre/Post Benchmark Data based on Race

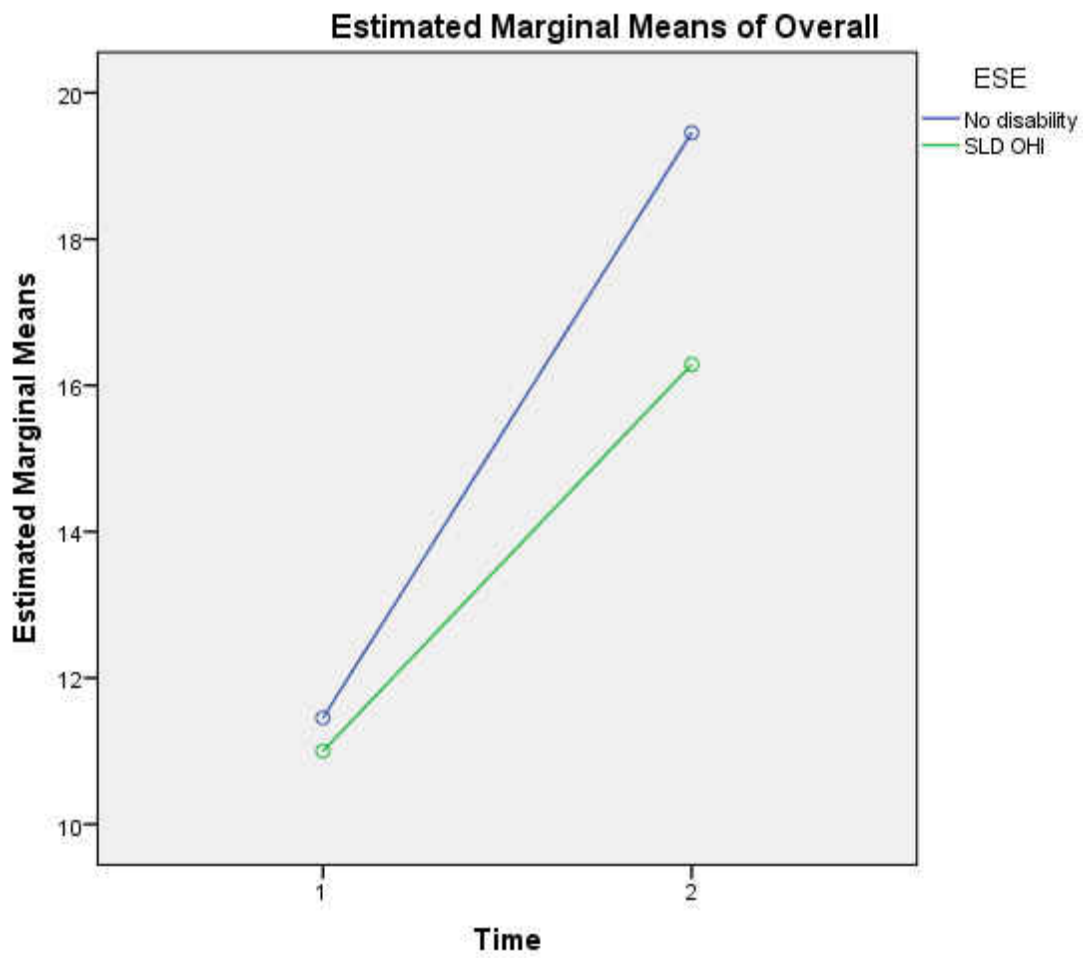


Figure 10: Pre/Post Overall Data based on ESE and Non-ESE population

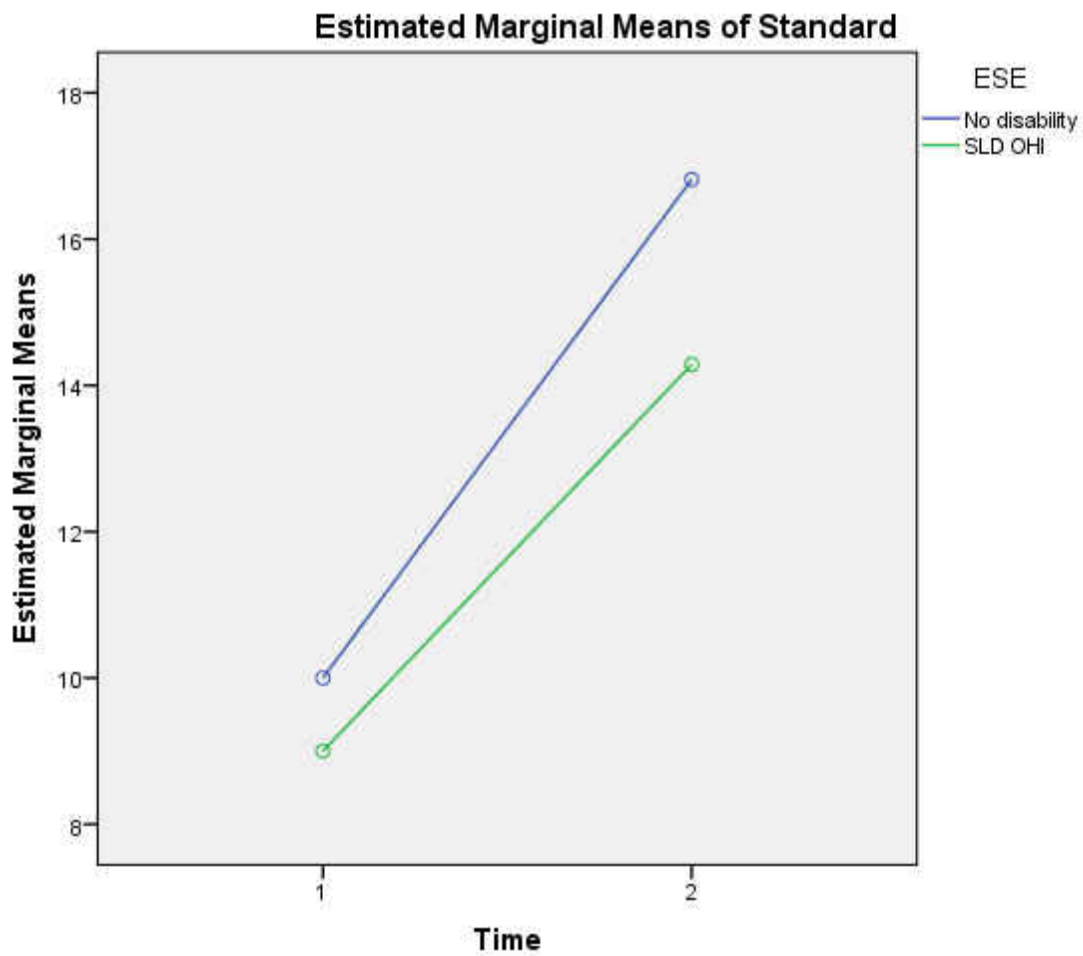


Figure 11: Pre/Post Standard Data based on ESE and Non-ESE population

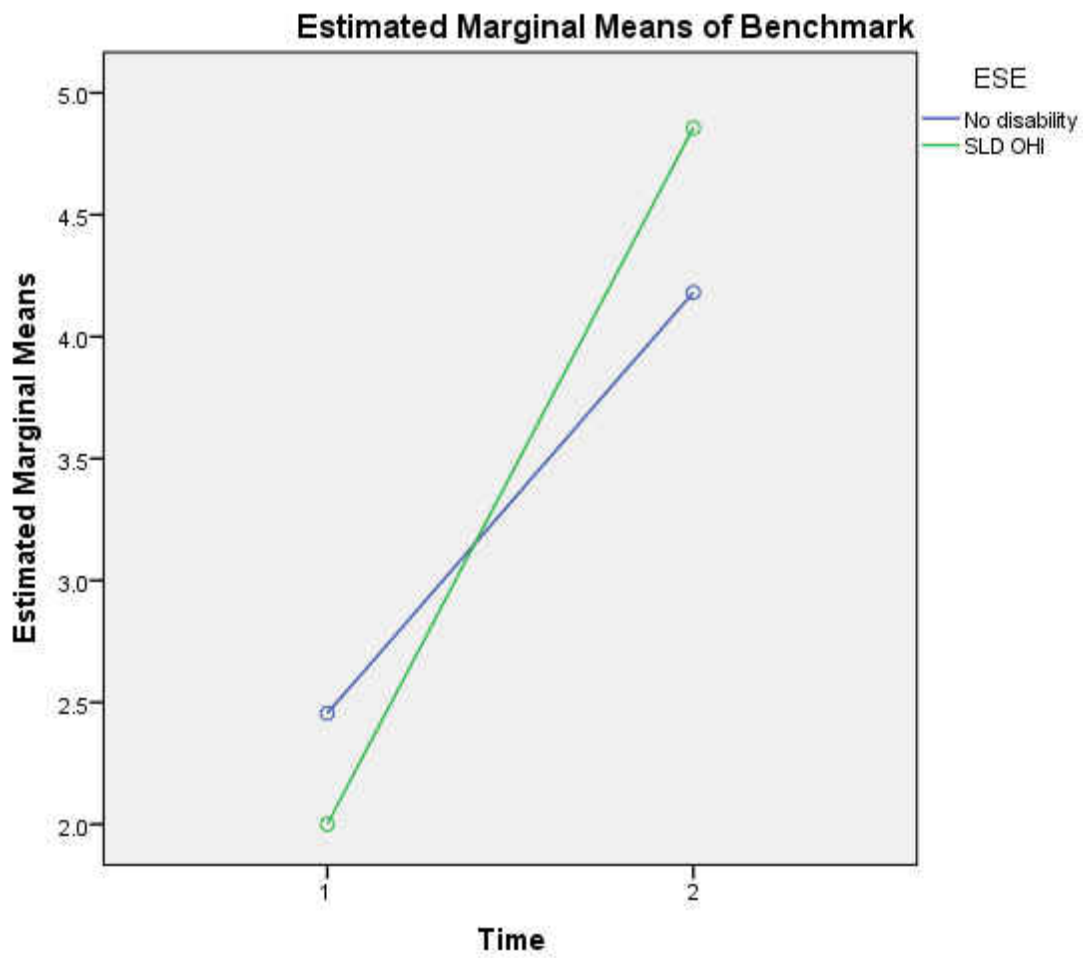


Figure 12: Pre/Post Benchmark Data based on ESE and Non-ESE population

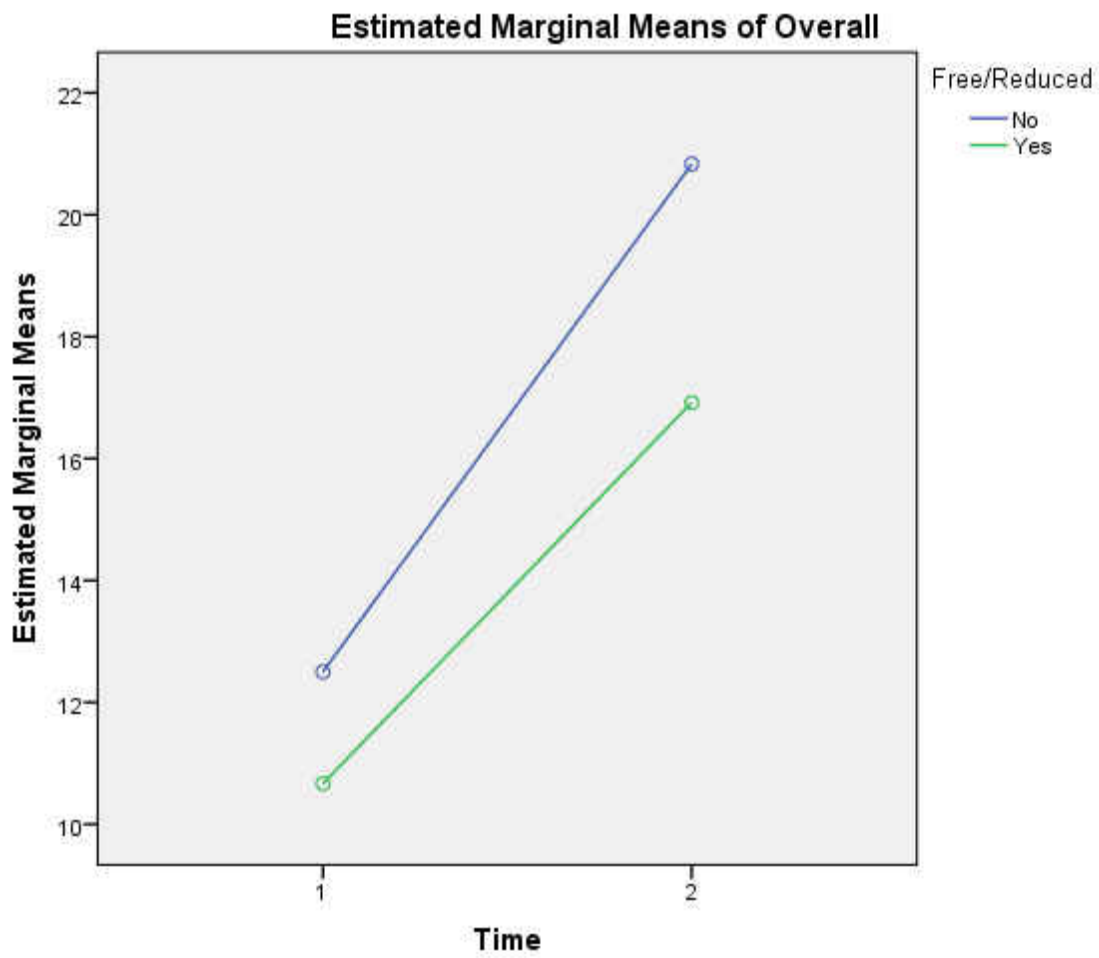


Figure 13: Pre/Post Overall Data based on Socio-Economic Status

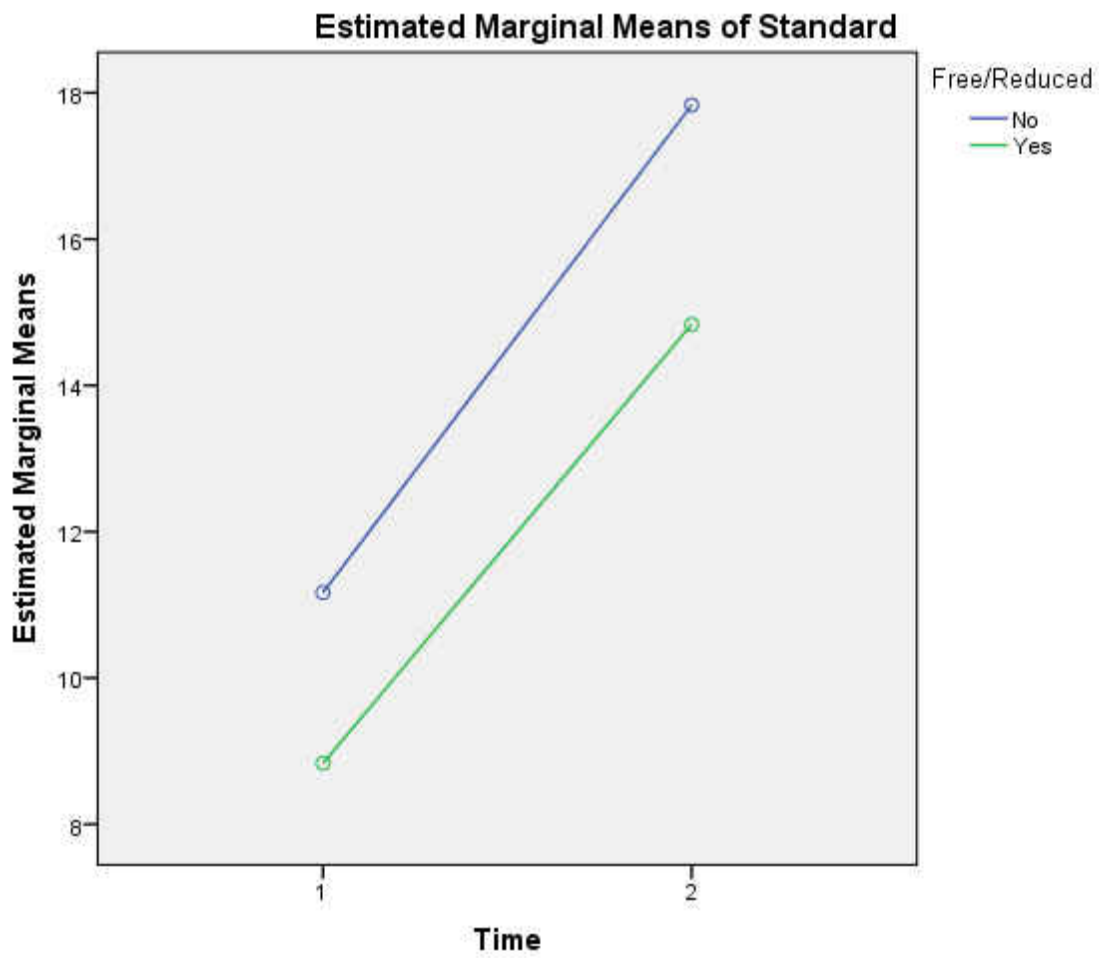


Figure 14: Pre/Post Standard Data based on Socio-Economic Status

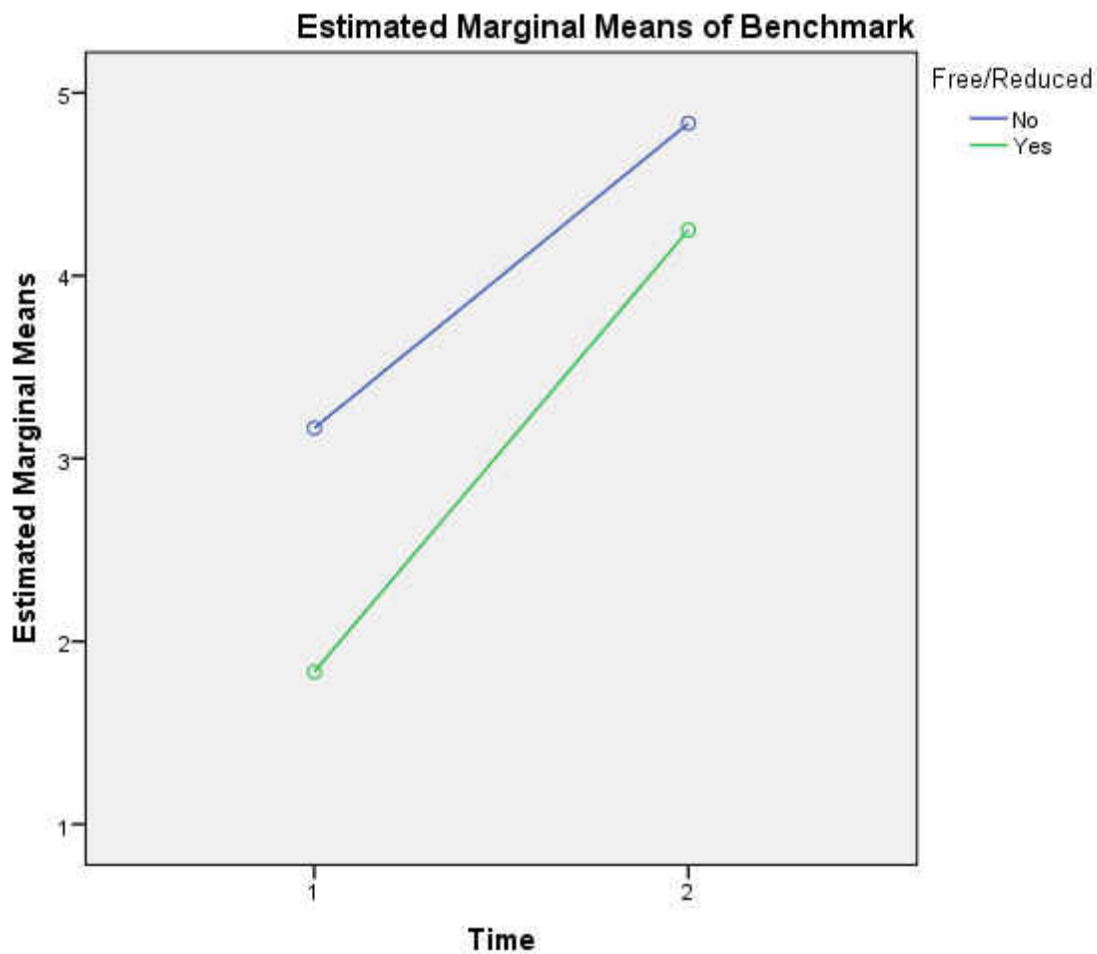


Figure 15: Pre/Post Benchmark Data based on Socio-Economic Status

In my final analysis of the research question: “How did the use formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?” The use of formative assessment classroom techniques provided me and student with immediate feedback of student understanding and performance. The observation of lab activities provided valuable feedback for teacher instruction. Student understanding of the language used on questions and schematics were paramount in students being able to perform well on assessment.

The use of formative assessment techniques and activities in the classroom helped students develop explanations for Sun-Earth-Moon phenomenon. However, writing in the content area was brought to the forefront of teacher observations as a weakness among the research group. Observations and themes in the analysis of this research question also were seen in the analysis of discourse. I found the use of formative assessment techniques to not only improve student performance but also made an easy transition to, if not in many cases, generated discourse among the members of the classroom. The use of formative assessments not only impacted student performance but a theme that emerged that influenced student performance was classroom climate. As the use of formative assessments progressed throughout the study, the climate of the classroom changed. Student involvement in activities and participation in formative assessments grew as students noticed their responses and ideas were presented to the class during instruction. As a teacher-observer, this was a change that was unexpected, yet welcomed and important to classroom performance.

Research Question 2: “How did the use of learning scales as formative assessment techniques impact student self-assessment of their knowledge of the Sun-Earth-Moon system?”

Seasons

A theme that emerged through analysis of the learning scale tracker was some students evaluated at a lower scale score after instruction than before. The use of the learning goal and scale tracker showed that at times, students assessed higher because they thought they knew the

material but upon further self-assessment students realized their knowledge base was inadequate to meet the targeted learning goal. For example, Joel had indicated he felt as if he knew less after the labs and readings than he did to begin with. When asked about his assessment, he recognized that before the lab he thought he could give a good explanation for seasons but now he realizes there were a lot of terms and concepts he did not think about and was unsure if he really understood. The use of the tracker and learning goal provided a means for the students to reflect on their first thoughts and assess their learning. The student self-assessment indicated that they may not fully understand the vocabulary or how to adequately explain the cause of the season in a scientific way.

ESOL and ESE students struggled with organizing their thoughts and completing the self-assessment without guidance. After noticing this trend, multiple sources of self-assessment were used to ensure that students were relating the material learned in class back to the learning goal. Just assessing before and after instruction was not enough. Self-assessment was needed throughout instruction. After self-assessment on this topic, I changed the way in which I elicited the information from the student. Instead of having the self-assessment only being in their folder, I also included it on exit slips and agree/disagree statements before introducing a lesson. Another technique, the use of traffic cups allowed students to assess their understanding during labs and on teacher-created tests. The traffic cups in some cases led to a lack of student focus and undesired behaviors, because they played with the cups instead of using them as an instructional tool. A variety of techniques were implemented to allow self-assessment to occur daily, such as thumb-up or down, the use of color coded stickers to post on a “parking lot” as students left the classroom to indicated their scale score. These techniques gave a day-by-day view of student

self-assessment and the data provided used to reinforce and target concepts to be re-taught when students showed they were on target.

Student reflections (APPENDIX: T-W), also showed they were beginning to acquire new vocabulary terms. Jamal wrote in his formative assessment folder, after the sticky-bar question, “Vernal Equinox is spring”. Eva also added, “A solstice is (when) we are tilted away or toward the sun. The equinox is when day and night are equal; they are caused by the tilt.” This showed the student may still have some misconceptions about the tilt of Earth changing; however, she recognized the terminology used for the seasons. Later she went on to write, “the tilt causes the seasons because it affects the temperature and the angle the sun is shining on the Earth.” The use of the learning scales and providing students with an opportunity to identify when their ideas changed helped them construct better explanations for the Sun-Earth-Moon system. Blaine provided an explanation on the back of his “Summer Talk” probe to adjust his explanation. He wrote, “Tilt. Summer is when the sun is shining directly at a certain part of the globe” he also included an illustration to indicate direct light hitting Earth. Blaine is a student with a specific learning disability and struggles to explain his ideas verbally and in writing but his response showed a better understanding of how to explain the reason for a season.

The results of self-assessment showed an upward movement in student-evaluated scores toward the learning goal, as shown in the figure below. A majority of students initially indicated they were at a level one or two and by the post-analysis students had moved from the lower assessment scores toward the target level of three. One theme that emerged was some students did not assess their learning with fidelity. Meaning, some students stated they started at a four and ended at a four, even though their performance on lab activities, classroom assignments and

discourse in class did not demonstrate a full mastery of the content taught. The accuracy with which they assessed themselves on the learning goal was not, for some students, a true representation of their understanding and performance toward the learning goal. Another trend emerged in regards to the after instruction assessment, was that students knew the target was a three, and the majority of the learning scale trackers indicated they perceived themselves to be a three. Upon analysis of self-assessment along with performance data and observations of student discourse, I think some students were not actually reflecting on the learning goal and where they were in relationship to it, they simply chose a three because that was where they were expected to be. Among ESE students, however, a theme emerged that they used the tracker to express that they were not fully understanding the concepts. This was valuable to me and the co-teacher because it made targeting student for remediation much easier. Furthermore, these students were given a voice and way to ask for help without admitting to the entire class they did not understand.



Figure 16: Student Self-Assessment Data--Seasons

Moonlight

The use of the probes also provided an avenue for students to self-assess. Some students chose to write beside their original response to indicate they assessed their original ideas and how it may have changed. Darrell, on the probe “Moonlight”, wrote below his explanation that he was wrong. After participating in discourse, he realized his justification was not factual. He did not explain why he was wrong, but noted that his original idea had changed. Other students chose to write their responses in their formative assessment folders. A caveat to this practice would be to provide more space for students to elaborate. Amy wrote in her folder, “I learned how the moon phases are caused and I learned it when we did our experiment about moon phases.” The student successfully reflected upon when her learning occurred during the lab where the students had to model the lunar phases using manipulatives. This feedback also gave

indication that inquiry-activities and experiences impacted student understanding. Maggie also wrote, “I learned that when people live on different sides (of Earth) from the Moon. The moon will always stay the same.” This was written after the probe “Gazing at the Moon” was administered and discussed amongst the class. Students were beginning to use and recognize that discourse from the probes and formative assessment techniques used in class, accompanied by the lab activities used in class were scaffolding their learning and fostering the development knowledge about the Sun-Earth-Moon system. The figure below shows movement in student assessment where a majority of students assessed initially as a one on the learning goal and in the post-analysis student moved more toward the target level three.

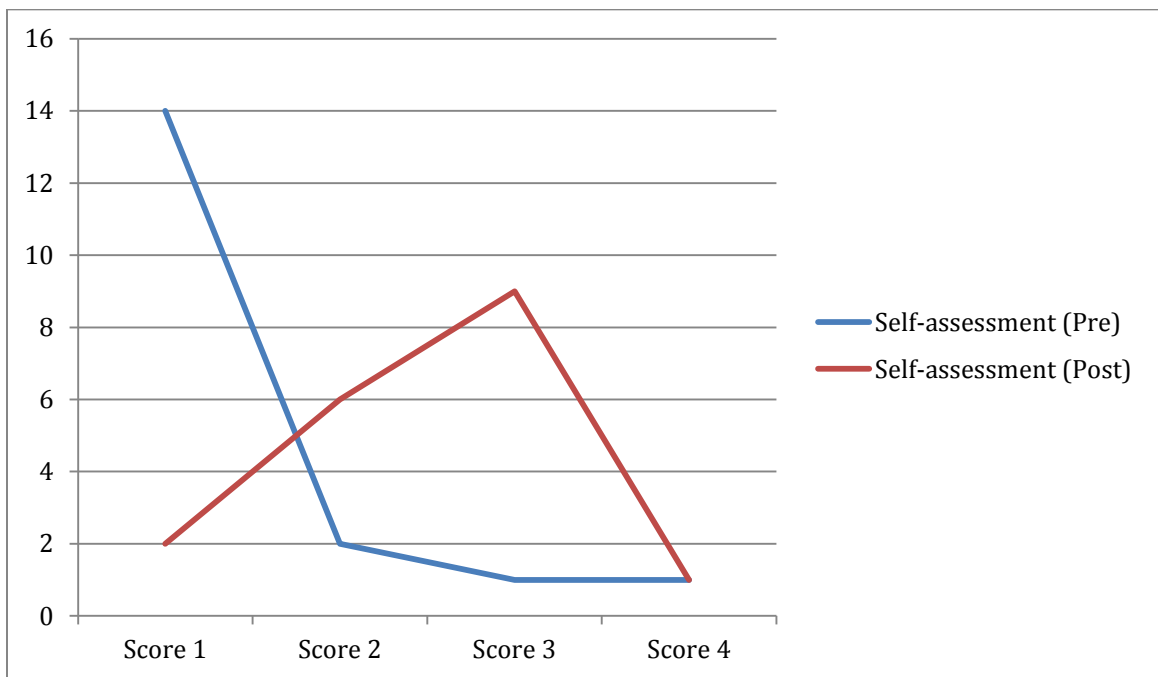


Figure 17: Student Self-Assessment Data--Lunar Phases

Tides

The learning goal and scale being placed on the exit slip also had unexpected results. Students were given another opportunity to share with me questions they may have. One student, Jorge, wrote a question, “What are tides?” on his exit slip. This was not the intended use of the exit slip, but a welcome one. When given the opportunity to assess their learning I found students divulged more information related to their misconceptions and gaps in knowledge which in turn, made it easier for me to develop lessons and focus on content that students had gaps in their knowledge of content related to the Sun-Earth-Moon system.

In addition to completing the exit slip, students also indicated their learning goal score on the exit slip. The learning goal target, three, indicated students could identify the position of the moon during spring and neap tide, define spring and neap tide, and explain why tides occur. Ten students indicated they were at level three. Four students expressed they were at a level two, which meant the student could identify the position of the moon during spring and neap tide. One student indicated he could use his knowledge of tides and apply it to a real world situation such as reading a tide chart for nautical activities. Students also graphed their learning goal scores in their assessment folders and learning scale tracking chart. Multiple opportunities for students to self-assess gave a better insight to where the students were in their learning and where gaps still existed. The results of this assessment, in the figure below, indicated many students started off with little knowledge of how the Sun-Earth-Moon system impacts tides. The post-analysis of student self-assessment showed students had closed gaps in knowledge and felt they were closer to the target level after engaging in lab activities and discourse about tidal phenomenon.

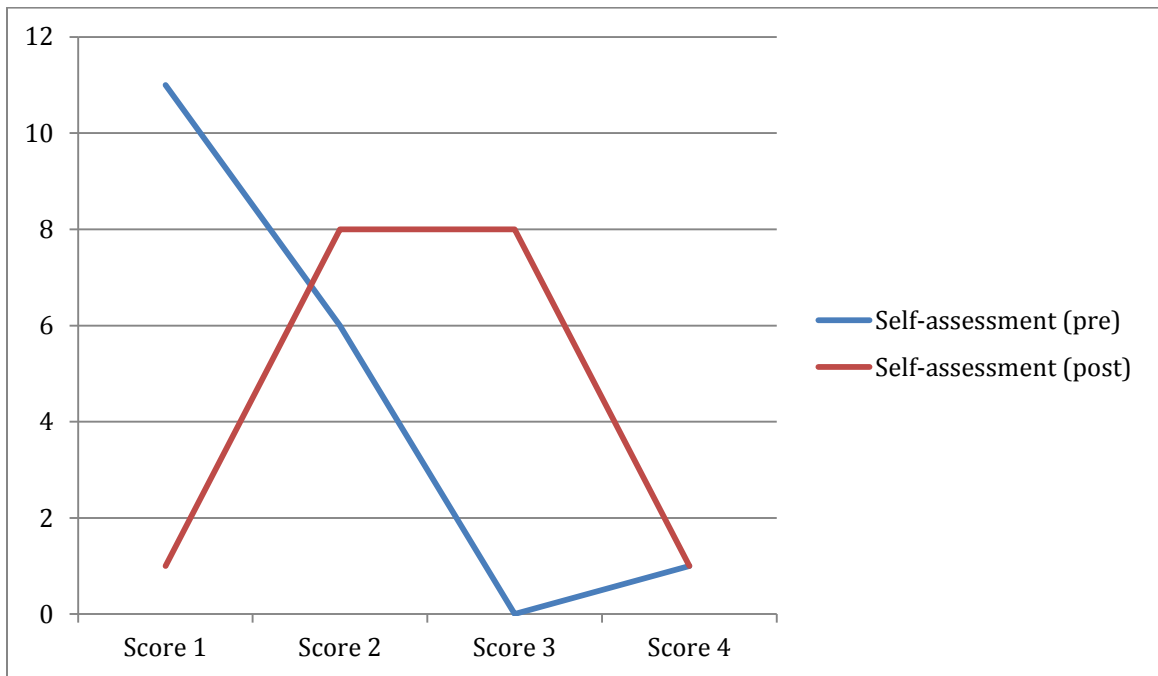


Figure 18: Student Self-Assessment Data--Tides

Eclipses

In their self-assessment, one of the two students who had rated themselves as a level four adjusted and changed to a level three. One student assessed as a level one, when asked why he (Jamal) rated himself as a level one he responded “I forgot where it (Sun, Earth, Moon) is (in eclipses).” There were four that self-assessed as a level two. One was surprising to me, Avery. When I asked Avery why he went from a three to a two, he stated, “I though he knew too much to begin with, I think I understand it but I was not sure of some of the vocabulary like penumbra and umbra.” Six students evaluated at a level three, while three students assessed as a level four. Teachers using learning goals and students self-assessing on learning goals provided feedback for the teacher and allows for self-reflection to occur among students. The figure below shows an equal number of students in the pre-analysis of the learning goal scored at a level one or two.

The post-analysis showed only one student still assessed at a score level of one while the students at level two decreased and student made an upward movement toward the target level of a three on the learning goal.

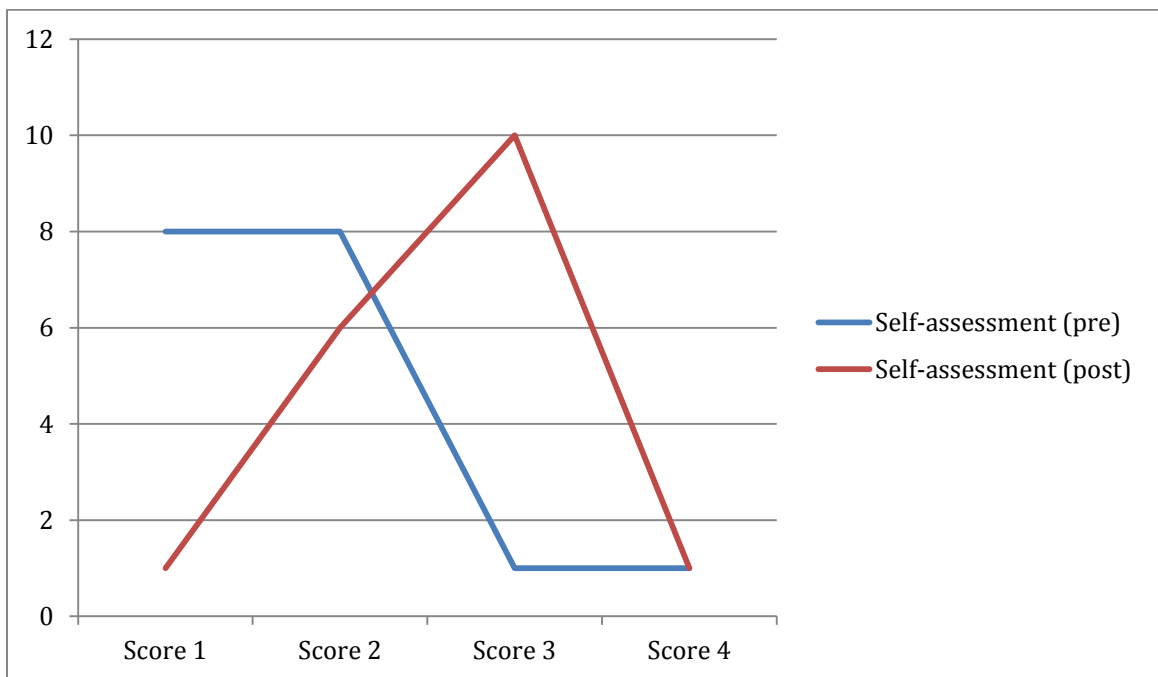


Figure 19: Student Self-Assessment Data--Eclipses

Student interview

In response to the question, “Did exit slips help you evaluate your learning?” Amy responded, “The exit slips helped my learning because it helped me realize what I really learned and helped me to see where I really was on the learning scale.” Jamal added to Amy’s response by explaining his thoughts on exit slips and learning scales. Jamal said, “The scales, exit slips and activities were just extra paper. I did not always pay attention to them but I know they tell me what I need to know.” I responded, “What did you not like about them or why did you not always pay attention?” He stated, “I know the learning scales and agree-disagree statements told

me what I need to know but they did take time away from what we could be learning and sometimes I thought it was just a waste of time.” Amy reminded him and the group, “But the learning scales shows where you thought you were until you learned it then it let you know where you are now in your learning.”

Jamey also responded to the use of learning scales and added, “Learning scales and self-assessment kind of did not help me because it was just a way for the teacher to keep track of where you are.” Amy disagreed by stating, “This was the only class where we reviewed the learning goal before and after the lesson. I liked being able to see where I was before and what I now know. I know it is important for teachers to know where we are but I felt like I could track my learning and I was able to see what was important and if my ideas changed. But I do wish we could have spent more time on the star information because I liked learning about that better than about the Moon, tides and eclipses.” One theme that emerge from student interviews on their perception of learning goals and tracking their learning scale score was student who did not value the process often evaluated high and did not change their scale score from before the lesson and after the lesson. However, students who valued self-assessment were in many cases able to move more than one scale score, in most cases moving from a one to a three.

Self-assessment allows students to think about their learning. When students think about their learning and experiences that led to learning and sharing their ideas with each other and the teacher; teacher instruction can be improved upon to facilitate a change in student ideas, improve student science vocabulary and understanding, help foster better explanations for scientific phenomenon, and make gains in student performance. Through the use of formative assessment,

student experiences in the classroom, and students realizing they were learning student involvement improved.

Research Question 3: “How did the implementation of formative assessment techniques affect student discourse on the topic of the Sun-Earth-Moon system?”

Seasons

One recurring theme that emerged in both performance data and discourse was student gaps in knowledge, especially when understanding science schematics, graphs and diagrams. Formative assessment classroom techniques, talk-friendly probes, sticky bars and exit slips were used to elicit student responses, student discourse during the use of probes and lab activities, and teacher observations were used to triangulate data. Students engaged in discourse and were able to share their knowledge with the class to help struggling learners understand science-related diagrams. One such instance was evident during the discussion of a sticky-bar response. Some students did not possess the background vocabulary to differentiate between latitude and longitude; they also were not accustomed to seeing a schematic of the Earth with the axis illustrated. When the class looked at the question and diagram, a student remarked, “How do we know if the latitude is north or south and what are the lines sticking out of the top?” Jamal responded to the student saying, “the lines sticking out of the top are the poles and the latitude on top is north, the one on bottom is south, and the one in the middle is the equator.” In the first question, all but four students correctly identified the season as summer. The other four chose winter. This provided feedback that students did not connect the tilt of the Earth with direct

radiation from the Sun on the hemisphere that is experiencing summer. The second question gave students four reasons to choose from to explain their thinking. Fourteen students correctly identified (1) The Sun is directly overhead at 23.5 degrees North at this time and six students responded (4) The Sun is directly overhead at 23.5 degrees South at this time.

When discussing the question, students again voiced confusion over the pole markers and lines of latitude. In question six, four students thought (4) The sun is directly overhead at 23.5 degrees south at this time, it is winter in the Northern Hemisphere. Gary stated, "Because the North Pole was pointed away it must be winter and winter starts December 21st." Amy, who chose (2) as her response-(the correct response) added, "But January is in the winter also, you have to read the questions." Four other students agreed with Amy; however, six disagreed and chose (3) The Earth is at autumnal equinox, it is September and fall is starting, sun's direct rays hitting the equator. Maggie and Amy both raised their hands, and Maggie responded, "September was not a choice and we have to decide what response best explains our thinking. If you read the question closely you will know you can choose September and March makes the most sense because direct sunlight is hitting the equator in the picture. Equinox means equal day and night." Blaine included, on a student reflection in his formative assessment folder, a schematic that indicated the pole direction as being a reason for the change in seasons. Discourse on the formative assessment technique allowed students to share their ideas and explanations of the cause of seasons. Student involvement allowed students to use student-friendly language to explain how to understand questions and science illustrations.

Moonlight

The use of probes as a formative assessment technique exposed student misconceptions and deficiencies in written explanations. The second probe used to elicit student ideas about the Sun-Earth-Moon system and the cause of lunar phases was “Going Through a Phase”. The scenario in this probe took place in a classroom where students gave their ideas about what causes the different phases of the Moon. The eight individual responses in the probe provided the action research students with explanations for a phase changes and they had to provide justification for why they chose the explanation. Three students provided no response for this probe. Only two students chose the correct response, “Parts of the Moon reflect light depending on the position of the Earth in relation to the Sun and Moon” (Keeley, 2005, p.185). Of the two correct responses, Raul provided no explanation; however, Amy wrote, “Because the phases of (the) moon happen when (the) position of Earth changes also where the Sun reaches the Moon.” This formative probe was helpful in understanding student thinking. Seven students agreed with the statement, “The phases of the Moon change according to the season of the year” (Keeley, 2005, p.185). Abby started the conversation by reading her response, “The moon does change in the seasons”. The class was asked whether anyone agreed or disagreed with Abby. Paul stated he agreed with Abby because “the Earth’s tilt causes seasons so the seasons might cause the moon (phases).” Jamal added “In different seasons the moon looks different.” Raul objected to Paul, his table partner, and Jamal’s responses and said, “If that were true we would only have a full moon each season and I know we see more than four full moons every year.” Jessica was then prompted to read her response. She agreed with her table partner Paul, and she agreed with

Jared's response (a student response written in the probe) because, "the phases of the moon change according to the season of the year because the phases change through the season and year." The class was asked again whether anyone has any other ideas that disagree or do not support Jared or Sophia's response. Four students indicated they agreed with the response on the probe given by Drew which stated, "Earth casts a shadow that causes a monthly pattern in how much of the moon we can see from Earth" (Keeley, 2005, p.185). Jamey shared that the Sun casts a shadow on the Earth. To that response, Dora said she thought "because it depends on the way the Earth casts a shadow on the moon and it shows either the whole moon or part of it." Maggie and Eva agreed it was because the Earth's shadow is on the moon. Eva then paused and added, "Or it could be Oofra's response," which read, "The shadow of the Sun blocks part of the Moon each night causing a pattern of different moon phases." Maggie quickly added, "But the Sun doesn't have a shadow it is a ball of burning gas with light coming out, it doesn't have a dark side." Eva then said, "Oh yeah that's right, it (the Sun) is a star." In the assessment folders, three students provided no response and one student rewrote the response but agreed with the statement, "The moon grows bigger each day until full then gets smaller and repeats this cycle every month." (Keeley, 2005,p. 185). The analysis of student responses reaffirmed that students need more opportunities to develop and write explanations. Eva's idea that the Sun had a dark side may have been reinforced by using a flashlight to simulate the Sun's light, in future lab activities the flashlight was replaced by a lamp, when before (during the instruction of seasons) a flashlight was used and may have influenced the student's initial response of thinking the Sun had a dark side. Student responses allowed me to evaluate and improve the manipulatives used during labs and throughout classroom interactions, so misconceptions are not perpetuated.

Student discourse appeared to have improved and frequency of probes used increased. Written responses were still not adequate for grade-level expectations but improvements in use of science language and gaps in knowledge were diminishing.

Tides

Discourse provided an appropriate platform to introduce new vocabulary and concepts. During and after lab activities time was allowed for and participating in discourse were encouraged, and brought student misconceptions and difficulty in understanding phenomenon of the Sun-Earth-Moon system to the forefront of class discussion. By listening to student explanations and analysis of lab data, new vocabulary and concepts was presented to explain tidal phenomenon. During a lab, which required students to graph tides at various locations during each lunar phase, Brody indicated the tide is the highest at his location during the full moon phases. Jamal, who had a different location, agreed and said, "Mine is too." I then asked the students to explain why they thought so, and after wait time was given no responses surfaced. As a class we continued to look at the data. Next, students took the last four dates and phases of the high tide and were asked to identify where high tide is the highest. Abby indicated her second highest high tide was during the new Moon phase. Gary and Joel, who had the same location, indicated to the class new Moon phase was also their second highest. Amy addressed the class and said, "So when the Sun, Earth, and Moon are in a straight line, our high tides are highest." At this point, I introduced the term spring tide. The classroom review and discourse continued to identify when high tide was the lowest. Blaine indicated out of his first and last four phases and dates the moon was at first and third quarter when high tides were the lowest. He

also added, that, when graphing his low tides, he noticed during these two phases low tides are at their highest. The term neap tide was introduced to the students. Maggie restated the data by adding, “When there are ninety degrees between the Moon and the Earth, the high tides are lowest and low tides are highest.” To reinforce this concept to ESE students and struggling learners, I showed a visual with my hand to indicate during spring tide there is the most change in tides, and during neap tide there is the least amount of change. Brody recognized the pattern on his graph. Discourse allowed students to think-aloud to develop a more accurate explanation of conceptual understanding of tides. This opportunity allowed for students to create challenging graphs that illustrated science content and students were able to interpret the graph and identify correlations in the lunar phase and the tidal height.

Eclipse

Discourse also allowed students to take ownership of their learning. Having manipulatives available during discourse allowed students to model their thinking and provided visual representations of Sun-Earth-Moon system phenomenon to other students. In probing student ideas for eclipses, we first completed the lunar eclipse probe. The class read the probe together and students took turns reading each choice. Students, then, individually chose which choice was the best idea to explain why lunar eclipses occur and explain their thinking about lunar eclipses. After students were given time to write and reflect, discourse was held to find out what ideas students agreed with and why. In the discussion five ideas were highlighted by the students as being possible explanations for why lunar eclipses occur. Two ideas garnered a majority of student responses: “The Moon passes between the Sun and the Earth” and “The Earth

passes between the Sun and the Moon.” Other ideas students supported included, “A nearby planet passes between the Earth and the Moon”, “The Sun passes between the Earth and the Moon”, and “The Moon turns to the dark side and then back to the light side.”

Dora began the discussion and stated she agreed with the idea that the Earth passed between the Sun and the Moon. She stated, “The sun shines on Earth and Earth’s shadow is on the Moon.” Avery said, “Yep, that what I said too. She is right.” Even though the two students were correct, I pressed the class for other ideas with which they agreed. Raul agreed with the idea that the Moon passes between the Sun and the Earth. He stated, “When the Earth, Moon, and Sun are perfectly aligned, the Sun’s color will reflect on the Moon.” Avery interjected, “That don’t make sense. The Sun reflects light that shines on the Moon. I don’t think the color of the Sun has anything to do with the eclipse, I think it is just a shadow.” Amy raised her hand to say she also agreed with Raul, “When the moon passes between the Sun and Earth, the sunlight’s reflection causes it to change colors. When it’s completely in front of the Sun, it darkens. Then it goes back to normal.” As the class drew to a close, Avery asked, “What’s the right answer?” I explained we would discuss it tomorrow, but if before class was over, he and two other students would like to take the flashlight, model Sun, Moon, and Earth and create a model to do so.

Avery, Jamal, and Maggie volunteered. Jamal took the light, Maggie the Earth and Avery the Moon. Some of their peers gathered around as I dimmed the lights the students began to model trying the Moon going in front of the Earth and Sun, then with the Moon going behind the Earth. As the Moon moved in front of the Earth, between the Earth and Sun, Avery claimed, “I knew it, I was right. See the Moon is in New Moon here it is casting a shadow on the Earth so on that spot (pointing to the shadow cast on the Earth) on Earth could not see the Sun.” He continued

showing his classmates by saying, “Now watch.” Avery placed the Moon behind the Earth. Maggie corrected Jamal asking him to hold the light still. Avery explained to Maggie and his classmates, “When the Moon goes behind the Earth it is Full Moon but if it goes in the shadow it will be blocked out, so that is the eclipse.”

Discourse also lead student to self-reflect and change their misconceptions. The day following the lunar eclipse formative probe, students were asked to share their ideas and how they changed after discussing the probe. Maggie was the first to reply, “I think my ideas changed. Yesterday, I thought “B”, (The Sun passes between the Earth and the Moon) because the orange(ish) color that the moon looks like when it (the Sun) passes it (the Moon). Now I think it is the other way around, when all are aligned, the Earth’s shadow covers the moon.” Jorge responded, “If the Sun passed between the Earth and moon, then that means the Sun orbits inside the planets (solar system). The Sun is in the center because it is the biggest thing in the solar system. If the Sun orbited it means that the other planets would have an orbit that would change.” I pressed him to explain. He said, “I mean don’t all the planets travel in the same orbit.” I responded, “Yes.” He continued, “Then if the Sun orbited so it would come between the Earth and the Moon it would cause our orbit to change because the position of the Sun changed.” I shared with the students the response of one of their classmates. One student, Susan, had agreed with the idea that a nearby planet passed in between the Earth and Moon. I did not share the identity of the student but did share her idea. Avery blurted out, “That’s just stupid.” After redirection and explaining when disagreeing with an idea be respectful and give reasons why you disagree, Avery continued. He stated, “I know that the planets all have a different orbit around the Sun; it is the planet’s year. There is not a planet that crosses our path only asteroids, meteors

and comets. That is why I thought it was a dumb idea.” In order for discourse to occur the teacher must provide a safe learning environment where all learners’ ideas are respected and responses are treated equal until disproven. Redirection and modeling of how to participate in discourse was of primary importance so more students felt free to share their ideas without judgment and the teacher gained a more complete picture of the differences in thinking among classroom participants.

The formative assessment probes, if related can be administered in sequential order and can reveal if students are able to apply previously discussed and similar concepts to different situations. Students were then administered the probe “Solar Eclipse”. After reading the probes and writing their responses students were asked to share their ideas. During discourse only one idea was discussed. A majority of the students agreed with the idea “The Moon’s shadow falls on the Earth.” Amy shared her response and stated, “It is when the Moon’s shadow falls on the Earth. I saw this yesterday when they (Jamal, Maggie and Avery) were working with the Moon, Earth and lamp (Sun) that when the Moon passes between the Earth the Moon blocks out the Sun for a few minutes.” Blaine stated, “I agree with her, the Sun gets blocked out when the moon passes through the sun and Earth.” I then asked, “Why doesn’t this occur all the time? Eclipses are rare.” Raul responded, “The Moon has to be perfectly aligned with the Earth and the Sun then for the (Moon’s) shadow to cover it (the Earth).” This response is evidence that discourse on the previous topic, lunar eclipses, impacted student understanding related phenomenon of the Sun-Earth-Moon system, solar eclipses. Students did have confusion over the exact alignment of the Sun-Earth-Moon system during this phenomenon and found it difficult to illustrate by drawing but illustrated more easily using manipulatives.

Student interviews

The two-tiered format of these probes provided students with real-world scenarios and engaged the learner on a level that developmentally appropriate. Overall students seemed to enjoy the probes and were not only an effective way for me to elicit ideas, but also made the content more applicable to the student. Student responses indicated students prefer a more hands-on approach and having manipulatives at their disposal allows them to show their ideas and helps them develop explanations for how the Sun-Earth-Moon system works. With respect to the probes, Jamal stated, “The probes were good because I could see an example on paper and the ideas were written from a kids’ point of view. It was written so I could understand what the probe was asking and it made the question more real to me.” Blaine added in respect to the probes, “I like when the learning was visual and some of the probes had pictures which helped me understand what the question was asking; maybe if we do more activities that are visual, maybe more imagining would mean more interaction and learning.” Abby added, “When we worked on the probes and then discussed the probes I could see my ideas were changing. There were some things I left out of my answers, and as we did more probes I learned to write all my thoughts down.”

Discourse was improved as more probes were administered and students were able to practice discourse. Discourse on not only the probes, but in response to formative assessment techniques provided feedback for teacher instruction and provided students an opportunity to develop and change explanations. Formative assessment techniques can be used to generate and enhance discourse and expose gaps in knowledge and misconceptions. The use of discourse also

allowed student to reflect on their own ideas and adjust those ideas based on discussions in the classroom. Teacher observations and student responses indicated the use of discourse was in formative for both the teacher and the student. As an educator, I was able to adjust my instruction and focus on specific vocabulary and ideas relating the Sun-Earth-Moon system. Students were able to share their ideas and hear opposing ideas and explanations to change their thinking.

In this chapter data was presented to answer the research questions. Themes that emerged were gleaned from the data analysis presented in this chapter. In chapter five I recapped studies that pertained to formative assessment and my action research. Limitations of this study were discussed and implications for future studies were explored. Chapter five summarizes the findings of this study.

CHAPTER FIVE: CONCLUSION

Introduction

In this chapter, I summarized chapters 1-4 of this action research. The research questions and purpose of the study were restated, and the literature review was summarized. The findings and interpretation of the study were discussed. Finally, I concluded with future implications for research on the topic.

The purpose of this study was to examine the impact of formative assessment on student performance data, formative assessments impact on student self-assessment, and effects the use of formative assessment has on discourse. The research questions were framed as follows:

1. “How did the use formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system?”
2. “How did the use of learning scales as formative techniques impact student self-assessment of their knowledge of the Sun-Earth-Moon system?”
3. “How did the implementation of formative assessment techniques affect student discourse on the topic of the Sun-Earth-Moon system?”

Prior studies have claimed teacher improvement of formative assessment produces benefits on mandatory assessments (Wiliam, Lee, Harris & Black, 2004). Formative assessment provides a source of data to inform educational decisions that guide instruction day-to-day and minute-by-minute (Leahy, Lyon, Thompson, & Wiliam, 2005). First, an interactive model for formative assessment in science was defined and discussed, which allows for the teacher to expose misconceptions if the teacher is familiar with a variety of assessment strategies in order to elicit student responses (Bell & Cowie, 1999). In regards to the second research question

students reflected on their own self-assessed learning and received peer feedback (peer-assessment), as well as reacted to their and others' evaluations of their learning. Formative assessment is not only made up of diagnostic assessments, but also peer and self-assessment (Chin & Teou, 2009). Finally, a fundamental characteristic of effective formative assessment was implemented to promote conversations and experiences that allowed teachers to listen to inquiry (Duschl, 2003). Discussion can be used to provide assessment opportunities if the time is taken to look and listen carefully to the talk and actions through which students develop and display their understanding. Discourse between students and teachers should be thoughtful, reflective, and focused in order to explore understanding, and enacted in a way that gives students an opportunity to think and express their ideas (Black & Wiliam, 1998). Research shows that the role and nature of discourse affects the quality of students' movement within discourse from formative feedback to assessment activities (Anderson et al., 2007). Research has shown formative assessment that is assessment for learning, has shown gains in student achievement, especially among low-achieving students (Black & Wiliam, 1998).

The data revealed several themes and implications for this particular population of students. In response to the first research question, how did the use of formative assessment affect student performance data in understanding the concepts of the Sun-Earth-Moon system, students saw an increase in their learning through the use of formative assessments. The pre/post-test data showed a positive impact in student performance data. Statistically significant gains were found as it related to the overall performance of all concepts taught and the overarching standard. However, performance on the standard improved but no statistical significance was found. One theme that emerged was ESE students' performance on pre/post-test

showed a higher gain in the post-test than their non-ESE counterparts. One theme, for this action research as it related to gender, that minority females performed better on the post-test than their male counterparts. However, white males performed at a higher level than their female counterparts. The results were not statistically significant but among this group of students this emergent theme was of interest. The average performance of the sub-groups when compared to each other showed that my practice of using formative assessment impacted the students with the greatest gaps in knowledge and they were able to close that gap.

Formative assessment techniques were easily used and effective for this population, when taking into consideration the time frame of the study and the varying levels of exceptionality in the classroom. One technique used, the Agree-Disagree statement exit slip, showed a student change in ideas over time. A formative assessment technique, sticky bars, was viewed as a review by some students and the teacher's observation showed had high frequent participation. This formative assessment technique gave immediate feedback to the teacher and allowed for direct instruction on the distracters chosen by and misconceptions held by the classroom participants. The impacts of techniques such as agree/disagree statements, whiteboards, and sticky bars provided immediate feedback. Other techniques, such as collaborative clues responses and traffic cups, produced unexpected results but were still valuable to the instructional practices of the practitioner. For example, the collaborative clues responses brought to the forefront weaknesses in the students' ability to peer-assess and develop conceptually accurate explanations of phenomenon within the Sun-Earth-Moon system. Traffic cups became a distraction to some students, however, the limited use of the traffic cups on teacher-created tests and assignments provided a way for students to signal to the teacher when

help or clarification was needed. Some students showed difficulty correcting incorrect responses of their peers, which exposed student weaknesses in developing explanations and peer assessment. The collaborative clues responses technique is one that is not always a ready-use technique, unlike the aforementioned agree/disagree, whiteboards, and sticky bars. Students need practice with this technique, which also requires thoughtful and strategic selection of the responses for students to analyze is important. Traffic cups, however, became an issue of focus for some students because students stacked or played the cups during instructional time instead of using them for their intended purpose. Techniques such as the whiteboards, annotated drawings, and sticky bars made student learning and student thinking visible not only to the educator and the student, but also to the student's peers as well. These techniques can serve as a starting point for discourse in the science classroom.

The second research question, how did the use of learning scales as formative techniques impact student self-assessment of their knowledge of the Sun-Earth-Moon system, also revealed interconnected themes that applied to performance and discourse. The probes, used for discourse, also served as a way for students to reflect on their learning before self-assessing after instruction. Students were able to identify and correct gaps in knowledge as it related to the Sun-Earth-Moon system.

The traffic cups were best used in this research on a sparing basis, such as during tests. During a test on the Sun-Earth-Moon system a student used a traffic cup to indicate she did not understand what the question on the test was asking. I was able to clarify the question to the students, which read, "When the side of the moon facing away from the Earth is fully reflecting sunlight, the moon is in the full moon phase." This question was a true/false question and the

student still did not understand after clarification. Then I asked the student whether the question could be drawn. I drew the sun for her and she drew where the Moon would be located if it were fully reflecting sunlight. The student then indicated she could now figure out the answer. Student feedback on the use of formative assessment techniques varied, but generally speaking most students could see a value in self-assessing their work. Of those who self-assessed before and after instruction occurred valued knowing what was expected of them and were able to meet the expected goal. As a teacher observer, the learning scales provided student feedback that allowed me to recognize individual students who assessed low and to provide them with guidance and instruction to impact their learning experience. The use of learning goals and learning scales, as a practitioner, made the goal of learner clearer and appeared to impact student performance positively. One student stated, “In other classes we just assess when an administrator is there or we just assess in the beginning. But I like [assessing] at the beginning and the end because I can think about if I really learned the goal.” As facilitator the learning goals made instruction much easier and the student feedback allowed me to target misconceptions and help students develop explanations for Sun-Earth-Moon phenomenon. The use of learning goals and framing of essential questions gave a clearer focus to the concepts taught in the classroom.

The final research question, how did the implementation of formative assessment techniques affect student discourse in the topic of the Sun-Earth-Moon system, revealed student participation increased with more frequent use of the probes? Not all students participated in discourse in the classroom which limited teacher insight to all students’ ideas and conceptual understanding. The use of formative assessment probes and explaining their thinking was a skill that students improved upon over time. In the beginning students were more reluctant to explain

their ideas. Some improvement was observed over time in student explanations and ability to explain and demonstrate conceptual learning of science topics. The use of the probes allowed student weaknesses in writing, developing explanations, and acquiring new science-related vocabulary to more accurately explain their thinking, exposed misconceptions. As more students felt comfortable to discuss their ideas they were more excited to argue their point and even demonstrate their thinking and explain why they disagreed with the ideas of others. For students that did not participate in discourse, the responses on the talk-friendly probes provided insight into their thinking and potential misconceptions. The use of inquiry-based activities allowed students to have experiences upon which to develop their explanations. When lab activities are integrated into the curriculum in a reflective way, students can be helped to develop a deeper understanding of content, as well as nature of science, and science reasoning skills (Singer, Hilton, and Schweingruber, 2006). Through this study I realized the value of these activities by the responses they elicited, the experiences they created, the questions students asked based on participating in the activities, and the implications they had for further discourse in the classroom. Discourse also, more than I realized, is an activity of listening where the teacher notices and recognizes student ideas and is able to respond to learners misconceptions or connect ideas to the learning goal of instruction.

Limitations

This study had a few limitations based on the analysis of results. Student attrition was to be expected; however, the degree of transience among this school's population was higher than I had previously expected or experienced. Before the study twenty-three students were in the

classroom, and over the duration of the study, their number decreased by five. Another limitation to the study was the co-teacher environment. Many participants in the study were students with learning disabilities. A new support-facilitator was introduced to the students during the second week of the study. This was the teacher's first experience working in a school setting and this was her first year in a new career field. Her limited experience working with ESE students may have impacted the quality and fidelity with which accommodations were provided to the students. The support-facilitator was a first-year teacher and was scheduled to service students one day a week in science. The limited amount of time the co-teacher was in the classroom impacted the familiarity the students had with the teacher and in some cases students showed reluctance to work with the support-facilitator. The time frame of the study was a limitation to the effectiveness of a variety of formative assessment techniques and student familiarity with the expectations of a variety of techniques. Furthermore, the two-week winter break may have attributed to student loss of knowledge after the break, which may have impacted performance data on the post-test. The varying abilities of student writing also limited the quality of student responses received. It is also unclear to what degree student perceptions of science or attitudes toward learning affected student performance.

Implications

In future research I would be interested in targeting more writing-based formative assessment to strengthen scientific writing. I would also be interested in student motivation as it pertains to using technology to administer formative assessment. Some students were reluctant to write their ideas, be it due to learning disabilities or student perceptions of writing. In a school

setting where technology is provided to each learner, I would be interested in the impact of use of formative assessments for student electronic collaboration. I noticed a change in the climate of the classroom, future studies should include a means to test classroom culture and the climate of the classroom to test for improvements in group dynamics when formative assessment techniques are involved. It would also be important to follow a group of teachers and students using a variety of assessment techniques to evaluate student performance, attitudes, and self-assessment as students become more accustomed to the use of formative assessments. Since a number of participants were classified as ESE, it would be important for educators to conduct further studies using a variety formative assessment techniques to best reach each type of learner. It is also of importance to the education community to target formative assessment techniques for their effectiveness for various sub-groups of students. Studies with more students would provide practitioners and researchers with more statistically significant results on which to base their decisions as to which techniques may work best with the types of students that are in the classroom. More qualitative studies on the impact of formative assessment has the potential to add to a growing body of best practices for educators.

Final Summary

This action research explored the use of formative assessment techniques and the impact on student performance, discourse and self-assessment. The research says formative assessment provides valuable feedback for teachers and use of discourse can become a platform for revealing student misconceptions as well as a means to provide feedback to students during the learning process. An essential part of formative assessment is that the students are engaged in

self- and peer-assessment. The way techniques and instruction are approached, such as inquiry-based activities, assessment probes, self-assessment, and learning goals can impact student performance and mastery of learning goals and objectives. Formative assessment techniques allow students to think about their learning and understanding. Formative assessment can also convey learning expectations to students. Techniques such as probes, discourse, and self-assessment not only identify misconceptions but help shape the learning environment.

Not all students in this study changed their misconceptions about the Sun-Earth-Moon system, but gaps in knowledge were narrowed. The use of formative assessment techniques had a positive impact on student pre/post-test results. The use of techniques such as talk-friendly probes, sticky bars, and agree/disagree statements provided student feedback to guide instruction. Teacher ability to elicit responses, notice and recognize student learning and participatory feedback, then use that feedback to direct instruction is essential in developing and utilizing formative assessment techniques to impact student learning. Formative assessment techniques provided a means to identified student misconceptions and gaps in knowledge as well as highlighted student weaknesses in constructing explanations for phenomenon within the Sun-Earth-Moon system. Written feedback among students and ability to formulate explanations improved for some students; however, they needed more practice to develop these skills. Students were able to convey through feedback difficulty understanding questions and diagrams presented during sticky-bars and agree/disagree statement feedback. These techniques resulted in classroom discourse and some students identified discourse and techniques used to impact their self-assessment toward the learning goal positively. Techniques used in this action research help to facilitate discourse and allowed students to practice and develop discourse skills in the content

area. Not all students participated in discourse, but as the class gained more practice with the skill more students participated. Discourse allowed students to discuss their misconceptions and ideas and provided an opportunity to close gaps in knowledge and change conceptual understanding within the Sun-Earth Moon system. The use of learning goals before and after activities helped students understand what was expected of them and self-monitoring of where a student perceived himself to be allowed them to identify changes in their thinking. Furthermore, student feedback from formative assessment techniques during discourse and teacher observation during labs and student self-assessment data provided clues as to which students required more individualized instruction and what concepts needed more attention. In this study, albeit a small population, ESE students showed gains in performance data, responded well to talk-friendly probes, participated in classroom discourse, and showed improvement on their self-assessment data in both agree/disagree statements and on the learning tracker. A more robust body of research regarding formative assessment techniques can better inform teachers as to which techniques may work best for their classroom population. All techniques may not work with all students but formative assessments are an effective means to inform educators, so instruction can change student ideas and close gaps in knowledge.

APPENDIX A: IRB RESPONSE LETTER



University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Clinton W. Anderson**

Date: **August 26, 2011**

Dear Researcher:

On 8/26/2011, the IRB approved the following activity as human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Project Title:	Probing Space: Exposing student ideas in astronomy
Investigator:	Clinton W Anderson
IRB Number:	SBE-11-07789
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in IRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 08/26/2011 09:31:07 AM EDT

IRB Coordinator

APPENDIX B: DISTRICT APPROVAL

Submit this form and a copy of your proposal to: **Accountability, Research, and Assessment**

RESEARCH REQUEST FORM

RECEIVED JUL 20 2011

Your research proposal should include:

- Project Title
- Purpose and Research Problem
- Instruments
- Procedures and Proposed Data Analysis

Requester's Name Clinton Anderson Date June 30, 2011

E-mail clinton.anderson@ Phone

Address Swallow Run
Street City, State Zip

Institutional Affiliation University of Central Florida

Project Director or Advisor Dr. Bobby Jeanpierre Phone 4078234930

Degree Sought: (check one) Associate Bachelor's Master's Specialist
 Doctorate Not Applicable

Project Title: What affects does the implementation and practice of formative assesment have on student performance in understanding astronomy concepts?

ESTIMATED INVOLVEMENT			
PERSONNEL/CENTERS	NUMBER	AMOUNT OF TIME (DAYS, HOURS, ETC.)	SPECIFY SCHOOLS BY NAME AND NUMBER OF TEACHERS, ADMINISTRATORS, ETC.
Students	25	Duration 1 9wks 15mins each day- on going	<u></u> -25 students
Teachers	1	60 days-on going	Clinton Anderson--Science Teacher
Administrators	1	60 days	Karen Furno--Principal
Schools/Centers	1		<u></u>
Others (specify)			

Specify possible benefits to students/school system: Assessing student learning styles to determine most effective formative assessments. Identify relationship between formative assessment and performance data, better inform instruction of educator, strengthen a teacher leader's practice regarding formative assessment so best practices can be shared with others in related professional learning communities

ASSURANCE

Using the proposed procedures and instrument, I hereby agree to conduct research in accordance with the policies of the Public Schools. Deviations from the approved procedures shall be cleared through the Senior Director of Accountability, Research, and Assessment. Reports and materials shall be supplied as specified.

Requester's Signature Clinton Anderson

Approval Granted: Yes No Date: 8-1-11

Signature of the Senior Director for Accountability, Research, and Assessment Nickie Cantwright

APPENDIX C: PERMISSION EMAIL TO USE KEELEY PROBES

Microsoft Office Outlook Web Access Type here to search This Folder Address Book Options Log Off

Mail Calendar Contacts Deleted Items (322) Drafts (8) Inbox (20) Junk E-mail (78) Sent Items

Click to view all folders... Manage Folders...

Reply Reply to All Forward Move Delete Junk Close

Re: Permission to use Formative Assessment Probes
 pagekeeley@gmail.com [pagekeeley@gmail.com] on behalf of Page Keeley [pkeeley@mmsa.org]

To help protect your privacy, some content in this message has been blocked. If you are sure that this message is from a trusted sender and you want to re-enable the blocked features, click here.
 You replied on 7/18/2011 9:24 AM.

Sent: Sunday, July 17, 2011 5:19 PM
To: Anderson, Clinton W.
Cc: Claire Reinburg [creinburg@nsta.org]

Dear Clinton,
 I am delighted to give you permission to use the probes in your action research study. Since these are your students, you are certainly welcome to make copies to use with your students. In terms of publishing your thesis, I don't think it is a problem using the probes as your thesis is not published commercially. I am cc'ing Claire Reinburg from NSTA Press just in case I am wrong.

I am delighted to hear from you and so pleased to know that the probes are making a difference in your teaching. I do hope when you finish your action research study you will share the results with me. I would love to learn more about your findings! Furthermore, Dr. Cary Sneider and I are finishing up the Astronomy version of Uncovering Student Ideas in Science. It won't be ready for publication until after your study but there may be some probes you might want to use (they will be in draft form). If there is a particular concept/topic you are looking for in Astronomy, please let me know and Cary and I would be glad to have you try it out in your study.

Best wishes to you in your Masters Program. I hope our paths cross again when I am in [redacted].

Best,
 Page

On Sun, Jul 17, 2011 at 4:51 PM, Anderson, Clinton W. <clinton.anderson@[redacted]> wrote:
 Mrs. Keely,

I am an 8th grade science teacher for [redacted], in [redacted], Florida. I am also pursuing a master's degree from University of Central Florida; as a requirement for graduation I will be conducting and publishing an action research thesis. A few years ago you came to speak to the science teachers in [redacted] and I had the pleasure to attend a training on formative assessment classroom techniques. In the years since I have implemented and modified these techniques into my practice and instruction and found them a way to keep learning exciting in the classroom. I will be researching the affects formative assessment has on students in performance and understanding of astronomy; I will also analyze the impact formative assessments have on student discourse and self-assessment. I would like to use a few of your probes that focus on astronomy, I may not use all of the probes but I believe I have identified a few probes that touch on the topics students often have misconceptions about, the probes I am referring to are titled: "Where do Stars Go?", "Moonlight", "Lunar Eclipse", "Solar Eclipse", "Emma's Moon and Stars", and "Objects in the Sky". When I receive my students in the fall I will administer a pre-test to illuminate their misconceptions and what concepts they struggle with, after analyzing the pre-test results I will utilize the aforementioned probes as needed. Is it okay with you for me to use some or all of these probes in my action research to gain a better understanding of my students' understanding and for qualitative analysis? I will certainly give you credit for your intellectual property and I have already used some of your ideas in my literature review on formative assessment (you are a wealth of knowledge) I have found your writing and work to be very helpful in my professional career, thank you for all your research and dedication to helping teachers better understand and assess their students' learning. Thank you for your time. I will await your reply and permission for use of these probes in my action research.

Thank you for your time and consideration,

Clinton Anderson

The information contained in this e-mail message is intended solely for the recipient(s) and may contain privileged information. Tampering with or altering the contents of this message is prohibited. This information is the same as any written document and may be subject to all rules governing public information according to Florida Statutes. Any message that falls under Chapter 119 shall not be altered in a manner that misrepresents the activities of Orange County Public Schools. [References: Florida State Constitution 1.24, Florida State Statutes Chapter 119, and OCPS Management Directive A-9.] If you have received this message in error, or are not the named recipient notify the sender and delete this message from your computer.

Page Keeley, MMSA Senior Program Director
 Past President of the National Science Teachers Association (NSTA) 2008-2009

APPENDIX D: PARENT ASSENT

Dear Parents,

As your child's science teacher, I am continually striving to become a better teacher. Currently, I am enrolled in a Master's program at UCF. This program is to help K-8 teachers teach math and science better. To finish my degree, I am writing an action research thesis examining my practice of teaching. My action research is to measure the impact of formative assessment techniques on student performance, self-assessment and discourse on the topic of the Sun-Earth Moon system. The Sun-Earth-Moon system will investigate seasons, lunar phases and moonlight, tides, and eclipses. Formative assessment techniques use student response to guide teacher instruction and assess learning as an ongoing process. The purpose of this study is to determine the impact of formative assessment techniques on student performance, self-assessment and discourse in the science classroom.

Audio or video taping:

Your child will be audio taped during this study. If you do not want your child to be audio taped, your child will not be able to be in the study. Discuss this with the researcher or a research team member. If your child is audio taped, the tape will be kept in a locked, safe place. The tape will be erased or destroyed when the researcher has presented and defended the findings of this study in the spring of 2012.

Your child will be videotaped during this study. If you do not want your child to be videotaped, your child will not be able to be in the study. Discuss this with the researcher or a research team member. If your child is videotaped, the tape will be kept in a locked, safe place. The tape will be erased or destroyed when the researcher has presented and defended the findings of this study in the spring of 2012.

Voluntary participation:

You should allow your child to take part in this study only because you want to. There is no penalty for not taking part, and neither you nor your child will lose any benefits. Formative assessment techniques will be used in this study will be taught regardless of your child's participation. If you choose to decline participation for your child, they will not take participate in the interview process. The data derived from their assessment responses and discourse will not be used in the study. You have the right to stop your child from taking part at any time. Just tell the researcher that you want your child to stop. Participation or nonparticipation will not affect any of your child's grades.

Thank you,

Clinton Anderson

Permission to participate in the study

Parent permission

APPENDIX E: STUDENT CONSENT

Hi I am Mr. Anderson, your Earth/Space Science Teacher. I am currently attending UCF pursuing my Master's degree. The program is to help K-8 teachers teach science and math better. To finish my degree I am conducting action research. My research project will examine the use of formative assessment techniques and how it can help students. The purpose of the study is for me to examine how my use of these techniques may impact your performance, self-assessment, and discourse. In order to complete this study I will videotape lessons in class and review your work. Please sign below if you agree to participate. If you do not participate it will not affect your grade, if you do participate it will not help your grade. This is just an exercise for me to become a better teacher.

Student Consent

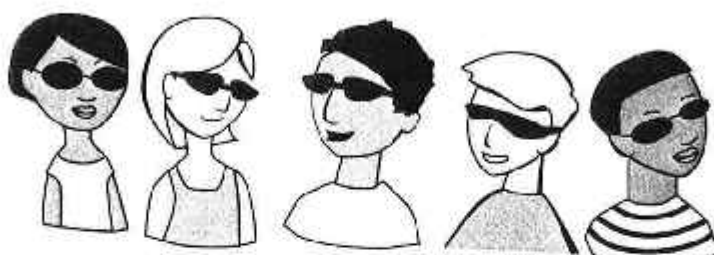
I, _____, realize I will not receive extra credit for participating, if I don't want to participate it will not affect my grade. I give Mr. Anderson permission to use my comments made during class discourse and my reflections and work in his research.

I agree to participate

I do not wish to participate

APPENDIX F: SUMMER TALK PROBE

Summer Talk



Six friends were talking. They each had different ideas about why it is warmer in the summer than in the winter. This is what they said:

Werner: "It's because the winter clouds block heat from the Sun."

Ava: "It's because the Sun gives off more heat in the summer than in winter."

Raul: "It's because Earth's tilt changes the angle of sunlight hitting Earth."

Fernando: "It's because the Earth orbits closer to the Sun in the summer than in the winter."

Shakira: "It's because one side of Earth faces the Sun and the other side faces away."

Susan: "It's because the Northern Hemisphere is closer to the Sun in summer than in the winter."

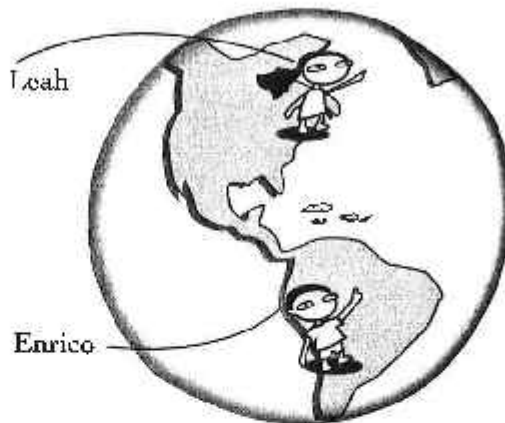
Which friend do you most agree with? _____

Describe your thinking about why it is warmer in the summer than in the winter.
Provide an explanation for your answer.

APPENDIX G: GAZING AT THE MOON PROBE

Gazing at the Moon

Enrico and Leah live in opposite hemispheres. Enrico lives in Santiago, Chile, which is in the Southern Hemisphere. Leah lives in Boston, Massachusetts, which is in the Northern Hemisphere. They both gazed at the Moon on the same evening. Enrico noticed there was a Full Moon when he looked up at the sky from his location (the Southern Hemisphere). What do you predict Leah saw when she looked up in the sky from her location (the Northern Hemisphere)?

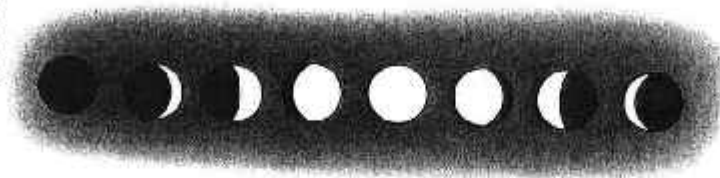


- A** New Moon (no part of the Moon is visible)
- B** Crescent Moon (a quarter of the face of the Moon is visible)
- C** Half Moon (half of the face of the Moon is visible)
- D** Gibbous Moon (three-quarters of the face of the Moon is visible)
- E** Full Moon (the entire face of the Moon is visible)

Provide an explanation for your answer. How did you decide what the Moon would look like in the opposite hemisphere?

APPENDIX H: GOING THROUGH A PHASE PROBE

Going Through a Phase



Mrs. Timmons asked her class to share their ideas about what causes the different phases of the Moon. This is what some of her students said:

Mona: The Moon lights up in different parts at different times of the month.

Jared: The phases of the Moon change according to the seasons of the year.

Sofia: Parts of the Moon reflect light depending on the position of the Earth in relation to the Sun and Moon.

Drew: The Earth casts a shadow that causes a monthly pattern in how much of the Moon we can see from Earth.

Trey: Different planets cast a shadow on the Moon as they revolve around the Sun.

Osira: The shadow of the Sun blocks part of the Moon each night causing a pattern of different Moon phases.

Natasha: The clouds cover the parts of the Moon that we can't see.

Raj: The Moon grows a little bit bigger each day until it is full and then it gets smaller again. It repeats this cycle every month.

Which student do you agree with and why? Explain your thinking.

APPENDIX I: MOONLIGHT PROBE

Moonlight

Five friends noticed they could see better at night when there was a Full Moon. They wondered where the moonlight came from. This is what they said:



Curis: "The Moon reflects the light from the Earth."

Chet: "The light from the Sun bounces off the Moon."

Clarence: "The Moon gets its light from distant stars."

Fallon: "The Moon absorbs light from the Sun during the day."

Deirdre: "There is light inside of the Moon that makes it shine."

Which person do you most agree with? Explain your thinking about moonlight.

APPENDIX J: LUNAR ECLIPSE PROBE

Lunar Eclipse

People have been fascinated by lunar (Moon) eclipses for ages. For a time, the full Moon seems to disappear as it changes color, darkens, and then reappears. Throughout time, people have had different ideas about what causes a lunar eclipse. Here are some of their ideas:

- A** A nearby planet passes between the Earth and the Moon.
- B** The Sun passes between the Earth and the Moon.
- C** The Moon passes between the Sun and the Earth.
- D** The Earth passes between the Sun and the Moon.
- E** The clouds block out the Moon.
- F** A nearby planet's shadow falls on the Moon.
- G** The Moon's shadow falls on the Earth.
- H** The Moon turns to the dark side and then back to the light side.

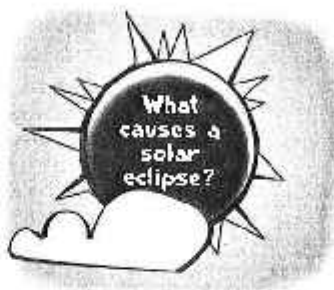


Circle the idea you think best explains what causes a lunar (Moon) eclipse. Explain your thinking about lunar eclipses.

APPENDIX K: SOLAR ECLIPSE PROBE

Solar Eclipse

People have always been fascinated by solar eclipses. During a solar eclipse, parts of the Earth experience darkness for a brief time during the day. Throughout time, people have had different ideas about what happens during a solar eclipse. Here are some of their ideas:



- A One of the nearby planets passes between the Sun and the Earth.
- B The Sun passes between the Earth and the Moon.
- C The Earth passes between the Sun and the Moon.
- D The clouds block out the Sun.
- E The Earth's shadow falls on the Sun.
- F The Moon's shadow falls on the Earth.
- G The Sun shuts off light for a few minutes.
- H The Sun moves behind the Earth for a few minutes then comes back again.

Circle the letter of the idea that you think best explains what happens during a solar eclipse. Explain your thinking about solar eclipses.

APPENDIX L: STUDENT LEARNING SCALE TRACKER

APPENDIX M: SEASONS LEARNING GOAL

Learning Scale

Score	Learning Goal: <i>explain the effect of Earth's tilt and position in orbit on Earth's seasonal changes. SC8E5.9</i>	Sample Activities
4	In addition to score 3, student will be able explain how the Earth's climate and seasons would vary if the tilt were different.	In addition to score 3, you can infer what happens or has happened when Earth's axis precession has changed the tilt angle of the Earth.
3	Student will be able to <i>explain the effect of Earth's tilt and position in orbit on Earth's seasonal changes.</i>	<ul style="list-style-type: none"> •You can demonstrate the position of the Earth during the seasons •You can define solstice and equinox •You can define aphelion and perihelion •You explain direct and indirect solar radiation
2	Student will be able to determine how the Earth's tilt affects seasonal changes.	<ul style="list-style-type: none"> •You can identify position of axis during the seasons •You can identify solstice and equinox in a picture
1	With help, student will be able to determine how the Earth's tilt affects seasonal changes.	

APPENDIX N: LUNAR PHASES LEARNING GOAL

Strand: SC.8.E.5.9 Topic: Lunar Phases

Strand: SC.8.E.5.9 Topic: Lunar Phases		
Score 4.0	In addition to Score 3.0, students make in depth inferences and applications that go beyond what is taught.	<p align="center">Sample Activities</p> <ul style="list-style-type: none"> • You can illustrate and explain the lunar phases and impacts of the phases on tides. • You understand the illuminated portion of moon's relative to the position of the Earth-Moon during the phase and can explain how moon rise and set changes in the system.
Score 3.0	The student explain and model the lunar phases in relation to the position of the Earth-Moon system	<ul style="list-style-type: none"> • You can explain why the moon goes through phases • You can create a model of the view of the Earth-Moon system from space. • You can create a model of the lunar phases as they appear from Earth
Score 2.0	Student can identify the lunar phases or the position of the Earth-Moon system during the phases	<ul style="list-style-type: none"> • You can identify lunar phases and the order of the phases • You can identify the position of the Earth-Moon system during new and full moon phases
Score 1.0	With help, student can identify the lunar phases or position of the Earth-Moon system during the phases.	

APPENDIX O: TIDES LEARNING GOAL

Learning Scale

Score	Learning Goal: <i>explain the lunar tide phenomenon in terms of the relative position of the Sun, Earth, and Moon. SC8E5.9</i>	Sample Activities
4	In addition to score 3, student will be use lunar tides in real world scenarios	You can determine the position of the Sun-Earth and Moon using a tide chart.
3	Student will be able to <i>explain the lunar tide phenomenon in terms of the relative position of the Sun, Earth, and Moon.</i>	<ul style="list-style-type: none"> *You can identify position the moon and sun during Spring tides and Neap tides *You can explain why tides occur *You can define apogee and perigee
2	Student will be able identify the moon's positions during low and high tides	<ul style="list-style-type: none"> *You can identify position of SEM during tides *You can define spring and neap tides
1	With help, student will be able identify the moon's positions during low and high tides	

APPENDIX P: ECLIPSE LEARNING GOAL

Learning Scale

Score	Learning Goal: <i>explain the lunar phase and eclipse phenomena in terms of the relative position of the Sun, Earth, and Moon. SC8E5.9</i>	Sample Activities
4	In addition to score 3, student will be able use scientific terminology to define the parts of an eclipse	You can correctly identify penumbra and umbra
3	Student will be able to explain <i>explain the lunar phase and eclipse phenomena in terms of the relative position of the Sun, Earth, and Moon.</i>	<ul style="list-style-type: none"> •You can identify position of SEM •You can explain why entire planet is not effected by every eclipse •You can explain why it doesn't occur in every lunar cycle
2	Student will be able identify and define and a lunar and solar eclipse	<ul style="list-style-type: none"> •You can identify position of SEM •You can define lunar and solar eclipse
1	With help, student will be able identify and define and a lunar and solar eclipse	

APPENDIX Q: LUNAR PHASES AGREE/DISAGREE STATEMENTS

Learning Goal: Identify the position of the SEM system to create eclipses; why an eclipse occurs.

	Agree	Disagree
Eclipses occur once a month because the Sun, Earth and Moon are on the same orbital plane.		
A lunar eclipse occurs during the full moon phase.		
The corona is the only part of the Sun seen in a full solar eclipse.		
There are total and partial eclipses of both the Sun and Moon.		
A solar eclipse occurs during the full moon phase.		
Everyone on planet Earth can see an eclipse when it occurs.		

Learning Scale Score: pre _____ post _____

0-I do not understand what the learning goal is asking

1-With help I can identify the position of the Sun, Earth, and Moon during an eclipse

2-I can identify the position of the Sun, Earth, and Moon during an eclipse

3-I can explain why eclipses occur and identify the position of the SEM system during an eclipse

4-I can explain why eclipses occur and identify the penumbra and umbra during an eclipse

APPENDIX R: TIDES AGREE/DISAGREE STATEMENTS

Tides: A lunar phenomenon

	Agree	Disagree
The position of the Earth, Moon and Sun impacts the tides		
Most coastal locations on Earth experience two tides, high and low, everyday. Some experience only a high tide or a low tide daily		
Spring tide only occurs on March 21 st , the vernal equinox in the northern hemisphere and on September 22 or 23 in the Southern Hemisphere.		
During a neap tide, the moon is at a right angle to the Earth and Sun		
During spring tide there is the least tidal change between high and low tide		
The Moon pulls more on the water than the land		
The high tide is higher and the low tide is lower at high latitudes		

Based on the learning scale where are you today before beginning the activities and reading _____

0—I don't understand the learning goal

1— With help I can identify the moon's position during spring and neap tide

2 I can identify the moon's position during spring and neap tides and identify the effects on the Earth-Moon system

3—I can identify the moon's position during spring and neap tides, define spring and neap tides, I can explain why tides occur.

4 I can use a tide chart to determine the moons position relative to the Earth and Sun

APPENDIX S: ECLIPSE AGREE/DISAGREE STATEMENTS

Learning Goal: Position of the Sun-Earth-Moon during lunar phases

	Agree	Disagree
The moon reflects light from the Sun		
During the full moon phase the Moon is at a right angle to the Earth and Sun		
Sunlight reaches the Moon		
There are four lunar phases		
The moon rises and sets at the same time every day		
We only see one side of the moon from Earth		

Based on the learning scale where are you today, before we begin the activity _____

0-- I don't understand the learning goal

1-- With help, I can identify the phases and position of the Sun-Earth-Moon

2 -- I can identify the order of the phases and the position of the Sun Earth Moon in each phase


3-- I can create a model, as viewed from space and as viewed from Earth of the Sun-Earth-Moon system, to demonstrate the lunar phases

4-- I can infer how the lunar phase can impact tides and explain how moon rise and set will change throughout the lunar cycle

APPENDIX T: LEARNING SCALE TRACKER—STUDENT SAMPLE

APPENDIX U: STUDENT SELF-ASSESSMENT RESPONSES—SEASONS

Q Seasons tilt and seasons

News Feed	Week of: What's on your mind from science class? I used to think that seasons don't have to do with the tilt.
News Feed	Week of: What's on your mind from science class? The things that help the seasons is the North and South.
News Feed	Week of: What's on your mind from science class? The seasons deal with the tilt because the seasons change.
News Feed	Week of: What's on your mind from science class? The Earth's tilt causes the seasons because the sun's rays are shining somewhere else causing a change in temp.
News Feed	Week of: 12/2 What's on your mind from science class? An equinox is when there's an equal amount of day and night. Solstice is when there's more daylight than the other.
News Feed	Week of: 12/5 What's on your mind from science class? Equinox means equal day and night.
News Feed	Week of: What's on your mind from science class? Seasons 

Q Orbit tilt and seasons

News Feed	Week of: What's on your mind from science class? I used to think seasons were caused by the distance from the sun but now I know they're caused by the tilt.
News Feed	Week of: What's on your mind from science class? A solstice is over when we are tilted away or toward the sun. The equinox is when the day and night are equal. They are caused by the tilt.
News Feed	Week of: What's on your mind from science class? The tilt causes the seasons because it affects the temperature and the angle the sun is shining on the earth.
News Feed	Week of: What's on your mind from science class? I use to think that the seasons changed because of the distance but now I know it's because of the tilt.
News Feed	Week of: What's on your mind from science class? because I learned the earth tilt did not move.
News Feed	Week of: What's on your mind from science class? During the labs I learned the distance does not change temp.
News Feed	Week of: What's on your mind from science class? How would our season be affected if Earth were not tilted on its axis?

APPENDIX V: STUDENT SELF-ASSESSMENT RESPONSES—LUNAR PHASES

1 Lunar Phases	
News Feed	Week of: What I learned in science class is that the moon has 8 phases and that we only see one side of the moon. What's on your mind from science class?
News Feed	Week of: I would like to learn what the positions are when the moon is in an eclipse. What's on your mind from science class?
News Feed	Week of: I learned that the sun rotates, that the seasons are caused by the earth's tilt, and learned the 8 phases of the moon and their names. What's on your mind from science class?
News Feed	Week of: What's on your mind from science class? I learned that the phases between the sun and earth change because of the tilt.
News Feed	Week of: What's on your mind from science class? I have learned the moon reflects light from the sun.
News Feed	Week of: What's on your mind from science class? I learned it by taking notes. I hear my classmates explaining it.

2 Lunar Phases	
News Feed	Week of: I learned that when people live on different sides from the moon, the moon will always stay the same. What's on your mind from science class?
News Feed	Week of: Dec 13, 2011 What's on your mind from science class? I have an understanding of the moon phase and everything I just learned when reading and talk about the phases of the moon.
News Feed	Week of: I learned the phases of the moon and what's on your mind from science class? and why they change.
3 What I've learned!	
News Feed	Week of: I learned that the moon has 8 lunar phases. What's on your mind from science class?
News Feed	12/13 Week of: What's on your mind from science class? I learned how the moon phases are caused and I learned when we did our experiment about moon phases.

APPENDIX W: STUDENT SELF-ASSESSMENT RESPONSES—TIDES

News Feed

Week of: 1/6

What's on your mind from science class?
 I learned how the position of the moon affects tides and the difference from a spring and neap tide.

News Feed

Week of: Jan 12, 2012

What's on your mind from science class?
 I learn this week well about tides that tides occur by the earth and moon sun.

News Feed

Week of: 1/6/12

What's on your mind from science class?
 neap tides are a right angle.

News Feed

Week of: Jan 6th

What's on your mind from science class?
 Earth moon and sun impact tides.

News Feed

Week of: I have learned about tides and I want to learn how to read a tide chart.

What's on your mind from science class?

News Feed

Week of: I learned that we have low tides and high tides.

What's on your mind from science class?

News Feed

Week of: 1/6/12

What's on your mind from science class?
 I learned the tides are affected by the sun and moon.

Tides

News Feed

Week of: I now know that the sun is farther than the moon so the moon affects the tides.

What's on your mind from science class?

News Feed

Week of: I learned about neap and spring tide and that the sun affects tides to.

What's on your mind from science class?

APPENDIX X: STUDENT SELF-ASSESSMENT RESPONSES—ECLIPSES

Eclipse

Week of:
 What's on your mind from science class?
 I learned that the the corona is the little ring you see during a eclipses

Week of: I learned that the earth, the moon, and the sun have to be aligned to see a lunar eclipses
 What's on your mind from science class?

Week of:
 What's on your mind from science class? The moon covers the sun
 or: moon is making cover

Week of: 1/13
 What's on your mind from science class?
 I learned how solar and lunar eclipses occur. Also which moon phase ~~is~~ appears when they happen.

Week of: Jun 12, 2012
 What's on your mind from science class?
 What I have learn was that an eclipses is where the earth is block from the sun...

Week of: Jun 13, 2012
 What's on your mind from science class?
 I learned that an solar eclipses occur with a New moon and a lunar eclipses occur a full moon

Eclipse

Week of: a New moon, can cause a solar eclipse and a full can cause lunar eclipses
 What's on your mind from science class?

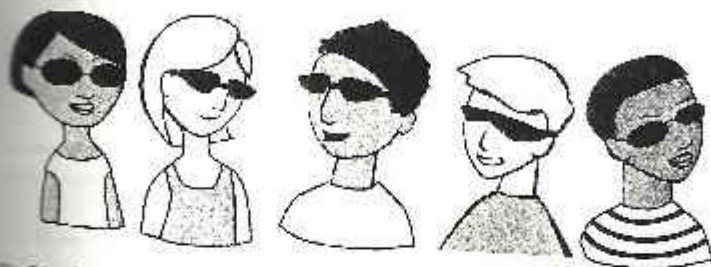
Week of: 1/13/12
 What's on your mind from science class?
 I learned that a lunar eclipse occurs during full moon

Week of: 1/13/12
 What's on your mind from science class?
 I learned that solar eclipses occur during new moon

Week of: 1/13/12
 What's on your mind from science class?
 I learned about both lunar and solar eclipses.

APPENDIX Y: STUDENT SAMPLE RESPONSE—SUMMER TALK PROBE

Summer Talk



Six friends were talking. They each had different ideas about why it is warmer in the summer than in the winter. This is what they said:

Werner: "It's because the winter clouds block heat from the Sun."

Ann: "It's because the Sun gives off more heat in the summer than in winter."

Raul: "It's because Earth's tilt changes the angle of sunlight hitting Earth."

Francisco: "It's because the Earth orbits closer to the Sun in the summer than in the winter."

Shakira: "It's because one side of Earth faces the Sun and the other side faces away."

Sam: "It's because the Northern Hemisphere is closer to the Sun in summer than in the winter."

Which friend do you most agree with? Raul

Describe your thinking about why it is warmer in the summer than in the winter.
Provide an explanation for your answer.

I think Raul is right
because the earth tilts and
makes the sun come closer.

APPENDIX Z: STUDENT SAMPLE RESPONSE—MOONLIGHT PROBE

Moonlight

Five friends noticed they could see better at night when there was a full Moon. They wondered where the moonlight came from. This is what they said:



Curtis: "The Moon reflects the light from the Earth."

Chet: "The light from the Sun bounces off the Moon."

Clarence: "The Moon gets its light from distant stars."

Fallon: "The Moon absorbs light from the Sun during the day."

Deirdre: "There is light inside of the Moon that makes it shine."

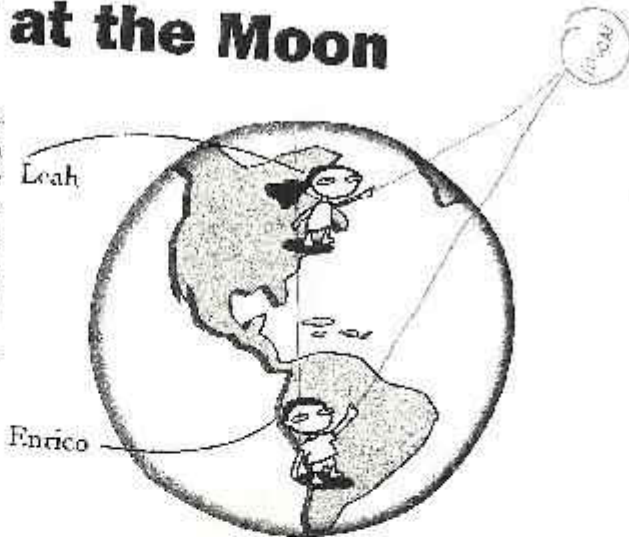
Which person do you most agree with? Explain your thinking about moonlight.

I agree with Fallon because
I think what he said is true
because the moon is always
hiding behind the sun
when it is daytime

**APPENDIX AA: STUDENT (ESE) SAMPLE RESPONSE—GAZING AT THE MOON
PROBE**

Gazing at the Moon

Enrico and Leah live in opposite hemispheres. Enrico lives in Santiago, Chile, which is in the Southern Hemisphere. Leah lives in Boston, Massachusetts, which is in the Northern Hemisphere. They both gazed at the Moon on the same evening. Enrico noticed there was a full Moon when he looked up at the sky from his location (the Southern Hemisphere). What do you predict Leah saw when she looked up in the sky from her location (the Northern Hemisphere)?

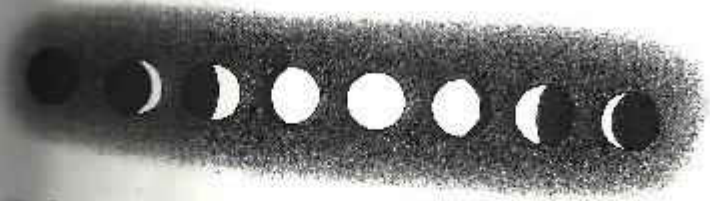


- A New Moon (no part of the Moon is visible)
- B Crescent Moon (a quarter of the face of the Moon is visible)
- C Half Moon (half of the face of the Moon is visible)
- D Gibbous Moon (three quarters of the face of the Moon is visible)
- E Full Moon (the entire face of the Moon is visible)

Provide an explanation for your answer. How did you decide what the Moon would look like in the opposite hemisphere?

APPENDIX AB: STUDENT SAMPLE RESPONSE—GOING THROUGH A PHASE

Going Through a Phase



Ms. Timmons asked her class to share their ideas about what causes the different phases of the Moon. This is what some of her students said:

- Mark: The Moon lights up in different parts at different times of the month.
- Janet: The phases of the Moon change according to the season of the year.
- Julia: Parts of the Moon reflect light depending on the position of the Earth in relation to the Sun and Moon.
- David: The Earth casts a shadow that causes a monthly pattern in how much of the Moon we can see from Earth.
- Tom: Different planets cast a shadow on the Moon as they revolve around the Sun.
- Clara: The shadow of the Sun blocks part of the Moon each night, causing a pattern of different Moon phases.
- Isabella: The clouds cover the parts of the Moon that we can't see.
- Sam: The Moon grows a little bit bigger each day until it is full and then it gets smaller again. It repeats this cycle every month.

Which student do you agree with and why? Explain your thinking.

I agree with Sofia because the phases of the moon happen when the position of the Earth changes. Also when the Sun reaches the moon.

APPENDIX AC: STUDENT SAMPLE RESPONSE—LUNAR ECLIPSE

Lunar Eclipse

People have been fascinated by lunar (Moon) eclipses for ages. For a time, the full Moon seems to disappear as it changes color, darkens, and then reappears. Throughout time, people have had different ideas about what causes a lunar eclipse. Here are some of their ideas:



- 1. A nearby planet passes between the Earth and the Moon.
- 2. The Sun passes between the Earth and the Moon.
- 3. The Moon passes between the Sun and the Earth.
- 4. The Earth passes between the Sun and the Moon.
- 5. The clouds block out the Moon.
- 6. A nearby planet's shadow falls on the Moon.
- 7. The Moon's shadow falls on the Earth.
- 8. The Moon turns on the dark side and then back to the light side.

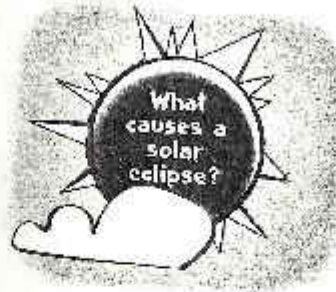
Circle the idea you think best explains what causes a lunar (Moon) eclipse. Explain your thinking about lunar eclipses.

1 because when the moon passes between the Sun and Earth, the sunlight's reflection causes it to change colors. When it's completely in front of the Sun, it darkens. Then finally it goes back to normal.

APPENDIX AD: STUDENT SAMPLE RESPONSE—SOLAR ECLIPSE

Solar Eclipse

People have always been fascinated by solar eclipses. During a solar eclipse, parts of the Earth experience darkness for a brief time during the day. Throughout time, people have had different ideas about what happens during a solar eclipse. Here are some of their ideas:



- A One of the nearby planets passes between the Sun and the Earth.
- B The Sun passes between the Earth and the Moon.
- C The Earth passes between the Sun and the Moon.
- D The clouds block out the Sun.
- E The Earth's shadow falls on the Sun.
- F The Moon's shadow falls on the Earth.
- G The Sun shuts off light for a few minutes.
- H The Sun moves behind the Earth for a few minutes then comes back again.

Circle the letter of the idea that you think best explains what happens during a solar eclipse. Explain your thinking about solar eclipses.

~~One of the nearby planets passes between the Sun and the Earth.~~
~~The Sun passes between the Earth and the Moon.~~
~~The Earth passes between the Sun and the Moon.~~
~~The clouds block out the Sun.~~
~~The Earth's shadow falls on the Sun.~~
 F The Moon's shadow falls on the Earth. This is what causes a solar eclipse because this can only happen once in a while and the moon's shadow never fall on the Earth only during a solar eclipse.

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