12-2021

Conceptual Insight into the Application of Innovative Educational Methods in Astronomy

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CONCEPTUAL INSIGHT INTO THE APPLICATION OF INNOVATIVE EDUCATIONAL METHODS IN ASTRONOMY

A Thesis

by

WAHLTYN A. RATTRAY

Submitted in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE IN INTERDISCIPLINARY STUDIES

Major Subject: Science Education

The University of Texas Rio Grande Valley

December 2021

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December, 2021

ABSTRACT

Rattray, Wahltyn A., Conceptual Insight into the Application of Innovative Educational Methods in Astronomy, Master of Science in Interdisciplinary Studies (MSIS), December, 2021, 56 pp., 7 tables, 5 figures, references, 10 titles.

University students taking introductory astronomy courses were studied with a control group enrolled in a class with standard curriculum and an experimental group enrolled in a class with a curriculum using innovative instructional methods. Using multiple assessments, I analyzed the students' astronomy knowledge and overall class experience to determine which curriculum was more instructionally effective. The innovative methods were developed with the ADDIE method and were based on the Karplus learning cycle which provided the framework for the astronomy curriculum. The end goal of the innovative curriculum is to produce graduates with better conceptual understanding of astronomy than with the standard curriculum. I have analyzed both the innovative and traditional methods and compared them based on data from student volunteers of both groups. The purpose of this thesis is to understand which method works best and identify the strengths and weaknesses students possess based on their total experience taking astronomy.

DEDICATION

The story of my journey would not be complete without the tireless dedication of my mother Maureen Livermore Rattray and my father Wesley Rattray. Their tireless support, care, and dedication has allowed me to grow into the strong person I have become. I am also grateful for my cousin, Thalia Bennett, who has shown genuine interest in my well-being and success over the years and has helped me through good and bad with her useful advice when I needed it the most, and for that I am truly grateful.

ACKNOWLEDGMENTS

I would like to thank Alan Hendrick, Moises Castillo, and Americo Hinojosa Lee for their support and friendship. They are thoughtful and inquisitive and were an instrumental part of my thesis journey and my physics education as well.

This would also not be possible without the dedication and professionalism of the professors on my committee. Thank you Dr. Mario Diaz for pushing me to be the best version of myself. Thank you Dr. Edgar Corpuz for your energy and support throughout my journey through graduate school. And thank you Dr. Natalia Guevara for your tireless dedication and genuine interest in my education since my undergraduate years.

To Robert Stone, the first face I saw from the physics department many years ago, thank you for your friendship. Also, I am forever grateful to Dr. Soma Mukherjee for her strong leadership and swift judgement, a shared trait with her constituents in the physics department at UTRGV. And I would be remiss if did not recognize Dr. Cristina Torres. The support she gave and the wisdom she shared throughout the years stay with me to this day, and I am greatly appreciative of that.

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CHAPTER I

INTRODUCTION

Education in astronomy is an enduring science which dates to the ancient human past. Human civilization has made groundbreaking advances throughout the centuries and with the help of technological breakthroughs, continues to this day. Game-changing discoveries were made by astronomers Johann Kepler and Galileo Galilei, with numerous artifacts and tools developed by early nations throughout the world, officially being the oldest and field of study for humankind.

Currently, astronomy is as relevant as ever. Based on prior data from the American Institute of Physics, there were 1,134 graduate students studying astronomy and completing their degrees in the United States in 2012 in the United States alone. This was a 50% increase from the same demographic during the 1960s. Much of this could possibly be due to the efforts made during the space program, however, even after the great achievements from NASA and other space agencies in the 1970s, this trend of success in astronomy education continued well into the 1990s. The highest numbers were seen in the 2010s, with favorable numbers still prevalent today.

For educators around the world, the main issue presented to us is that there is insufficient emphasis on science literacy found in modern curricula throughout our educational system. Every year, over 200,000 non-science major undergraduate students enroll in an introductory astronomy course in the United States. This is typically the final science course in their educational journey, and as a result, many students graduate with little interest in science and have large gaps in their astronomy understanding. I investigated this claim by reviewing a publication about the ASSCI, the Astronomy Space Science Concept Inventory exam. Written by an astronomer from the Harvard-Smithsonian who conducted extensive research into conceptual understanding of astronomical concepts of graduating students from Harvard University using a learning assessment developed by his team specifically for astronomy students to find that most lacked basic understanding of undergraduate astronomy concepts taught to entry-level students. This was done with the use of a concept inventory exam, an assessment used to assess student understanding of a specific topic.

For two semesters, the Spring, Fall, and both summer sessions in between, I conducted a study that explored the knowledge and perspectives towards astronomy held by undergraduate UTRGV students who enrolled in the Introduction to Astronomy 1401 course. There were two concurrent courses given during the semester that had contrasting structure of the curriculum. Students could choose which section of the course to enroll in but did were impervious to which style of curriculum they would receive. The first course curriculum was structured around the Karplus learning cycle that was developed decades ago and modified multiple times over the past few decades. The second course curriculum was a standard, more dated version which has been in use by the university for over a decade that was not based on the learning cycle. My goal was to interpret the efficacy of an innovative education curriculum based on the Karplus learning cycle and also the more modern version, the 5 E learning cycle, which is the most recent successor of the Karplus learning cycle and compare it to the standard curriculum used to teach astronomy education. This study goes a step further than other astronomy education research efforts in the past to illustrate a broader picture of the efficacy of the innovative astronomy educational methods used at UTRGV. This was done by using objective aspects of the course as well as subjective ones to sufficiently define the Astronomy 1401 experience. This results in a comprehensive metric to determine their retention of astronomy knowledge as well as their psychological experience which was measured through their "flow" state revealed by their evaluation survey. The level of flow experienced by the students is defined as an overall positive, negative, or neutral view of the course. This was acquired from the volunteers through a student evaluation questionnaire presented to the student volunteers probing their place on the flow vs. apathy scale. In addition, there was also an evaluation of the course instructors responsible for teaching the curriculum to those students, which ensured a more intimate view of the program effectiveness on both sides of the education process. The teacher-to-student instruction process was on one side, while the general learning experience by the students was on the other.

The Cristina Torres Memorial Observatory (CTMO) is the premier observatory at the university and the most sophisticated astronomy research facility of its kind found anywhere in the Rio Grande Valley of the South Texas region. This generates significant attention from members of the community as well as visitors to the region who came to know of the facility through recommendation.

CHAPTER II

REVIEW OF LITERATURE

Science Education in the 21st Century

The National Science Education Standards states that the way material is taught in the classroom is at the heart of effective science education. Students learn better when they can engage themselves in the material, making new discoveries in the process. This prompts the fact that a better learning environment is conducive to a better learning experience for the students.

2D and 3D Astronomy

In the proper learning environment, students can grasp material more effectively when they address each concept in multiple ways. This applies to astronomers as well, which is why there are many reasons that this is a beneficial approach to teaching astronomy. Many students can be intimidated by the breadth of material presented to them in an upper-level astronomy course. The same is also true when working with introductory astronomy students who do not have a strong science background.

One of the difficulties involved in accurately teaching and learning astronomy is the representation of three-dimensional objects on a two-dimensional page. This is an unavoidable reality since any material in textbooks can only be written in two dimensions. This means that depth of perception of astronomical objects is not learned accurately by the students through traditional teaching methods. When astronomers, expert or novice, observe the night sky, depth of perception is an unavoidable and completely natural limitation to the ability to accurately measure the distance of a point source anywhere in the celestial sphere. Brighter celestial objects that are farther away may seem comparable in size and brightness while dimmer celestial objects that are much closer may seem comparable to brighter objects farther away. For the astronomer, this means that unless the correct technique is used, there is no way to judge proper distance and have an accurate depth perception. This means that even when objects appear to be closer to us, the opposite may be true.

To help students understand the night sky and their place in the cosmos, I designed an astronomy laboratory assignment using an interactive method which involves two software programs as well as a hands-on observation segment that relates the covered concepts. This assignment was developed to help the student learn how to fundamentally conceptualize space and astronomical scales. This would assist in the instruction of astronomy and help to concisely solidify abstract concepts. In a paper written by Dr. Reynolds in 1990 titled Two-Dimensional Versus Three-Dimensional Conceptualization in Astronomy Education, he addresses the need for instructor awareness of dimensionality and student misconceptions.

Relevance of Laboratory Instruction

Laboratory instruction is a critical component of higher education in the sciences, although this was not always the case. In the mid-1800s, physics was taught mainly through recitation from physics textbooks and material obtained from joint lectures. This changed at the turn of the 20th century, with the growing popularity of lab instruction taking hold in the United

States. The reason for this is the acceptance of the idea that observation and manipulation were useful in the process of disciplining the mind. In the 1880s, lab activities were implemented into high school chemistry classes. Harvard University also incorporated lab instruction by publishing a list of physics experiments and positioning them to be included in high school physics classes. Harvard was able to benefit from this by reserving the class for potential future students aspiring to attend the prestigious university. The effectiveness of lab instruction was apparent due to its relevance in training students effectively in observation, ability to supply detailed information, and the beneficial effect of inspiring students in the laboratory.

The Learning Cycle

Over the last 60 years, the learning cycle has evolved into a bedrock principle in modern education. This is evident in the history and development of this cycle for many decades since its development by Robert Karplus and Atkin in 1962. Even this Karplus and Atkin learning cycle was not completely original but built on the foundation of Jean Piaget's 4 Stages of Cognitive Development theory in 1936. Piaget proposed that intelligence is gained in a series of stages throughout a child's developmental years. The qualitative and quantitative ways that children think vary as they age from an infant's discovery of the world through touch and motion to the deductive and logical ways of thinking that makes humans capable of understanding abstract concepts employed by fully developed adults.

The Karplus learning cycle was created in 1962 and is the forerunner of the more current 5 E Learning Cycle. Karplus and Atkin postulated three steps. The Karplus Learning Cycle is based on the following components:

1) Exploration

    Students explore new materials mostly on their own without much expectation of accomplishment.

2) Term Introduction

    A new concept is introduced to provide background for a particular idea.

3) Application

    Students apply the new concept they learned to new situations.

There are multiple learning cycles that currently exist as the result of illuminating research in the field. A learning cycle is defined as a term given to describe a sequence of instructional points used to generate conceptual understanding of a particular subject. The original learning cycle was developed by J. Myron Atkin and Robert Karplus in 1962 and led the way for subsequent research in the field of education. These two researchers based much of their work on Jean Piaget's four stages of learning which articulate cognitive development from subjects as young as newborns leading all the way up to those well into adulthood.

The most modern learning cycle consists of five stages known as the five Es. They were developed by the Biological Sciences Curriculum Study (BSCS) in 1987 and are the newest reiteration of the learning cycle dating the Karplus learning cycle by twenty-five years.

The 5 E Learning cycle:

1) Engagement:

    The teacher employs short activities that promote curiosity and elicit prior knowledge, connecting past and present learning experiences.

2) Exploration

    Students are provided with a base of lab activities that help them use prior knowledge to explore questions and possibilities and also generate new ideas.

3) Explanation

    The students' attention is focused on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding.

4) Elaboration

    Teachers challenge and extend students' conceptual understanding and skills by developing deeper understanding through new experiences.

5) Evaluation

    Students assess their understanding and provide opportunities for teachers to evaluate their progress toward achieving the educational objectives.

Flow

The psychology of flow is described as a person's state of mind that is characterized by a smooth and dreamlike experience without awareness of the passage of time while completing a challenging task. This very experience has been documented and experienced by many very successful individuals in the world at the top of their field. The merger of success and flow attribute its favorability to the results of those who experience it. The flow the student volunteers in this study experienced was measured through a survey based on a 5-point Likert scale and compared with the results of their traditional student counterparts.

Flow is characterized by the following experiences:

1) Completely involved in what we are doing – focused, concentrated.

2) A sense of ecstasy – of being outside everyday reality.

3) Great inner clarity – knowing what needs to be done, and how well we are doing.

4) Knowing that the activity is doable – that our skills are adequate to the task.

5) A sense of serenity – no worries about oneself, and a feeling of growing beyond the boundaries of the ego.

6) Timelessness – thoroughly focused on the present, hours seem to pass by in minutes.

7) Intrinsic motivation – whatever produces flow becomes its own reward.

A primary source defines flow in the following example:

"You are in an ecstatic state to such a point that you feel as though you almost don't exist. I have experienced this time and again. My hand seems devoid of myself, and I have nothing to do with what is happening. I just sit there watching it in a state of awe and wonderment. And [the music] just flows out of itself." – Musical Composer.

Concept Inventory Exams

Developing and Validating a Concept Inventory Exam

There are eight steps that are necessary to create a concept inventory exam as mentioned in .the ASSCI paper written by an astronomer of the Harvard Smithsonian Center for Astrophysics. This whole process is necessary for an accurate and reliable assessment to function effectively and it is an invaluable measure to ensure that the integrity of the assessment remains uncompromised.

The eight steps to developing a concept inventory exam are:

1) Review and catalog relevant misconception literature.
2) Use standards interpretation and draft item construction.
3) Review and validate the survey by an expert.
4) Conduct pilot testing by selected individuals.
5) Execute large scale validation.
6) Undertake item analysis.
7) Construct the final test instrument.
8) Perform field testing of the final test instrument.

Evidentiary Validity Framework of Concept Inventories

Many scientists that develop concept inventory exams pursue evidence of validity that support their exams. To prove the levels of validity of a concept inventory exam, the claims of the exam developer or users of that exam must be heard and ultimately validated. This leads to empirical and analytical proof of exam effectiveness. Only after this process is complete can the developer's claims about the exam measurement capacity be supported.

Concept inventory developers follow three principles pertaining to their exams:

1) Overall performance on the inventory measures the focal domain knowledge and individual items provide coherent data that can be aggregated into an overall measure of performance.

2) The instrument has subgroups of items that represent different domain concepts, therefore, one can examine performance on groups of items to measure understanding of individual concepts.

3) The instrument is able to reveal common student errors by means of distractor response patterns.

ASSCI Assessment

The innovative curriculum is a more current version of a lab curriculum that has existed for many years before. These lab assignments have been moderately successful in educating undergraduate non-science astronomy majors, however there was an apparent need for improvement. In 1993, the Harvard-Smithsonian Institute conducted a survey of graduating students from Harvard University probing their understanding of basic astronomy concepts. A paper was written titled "The Astronomy and Space Science Concept Inventory: Development and Validation of Assessment Instruments Aligned with the K-12 National Science Standards." An accompanying documentary film was also made titled "A Private Universe." Surprisingly, the survey showed that most students possessed completely inaccurate views of astronomical concepts and showed poor understanding of the basic mechanics of the universe. This was evident in the documentary, illuminating the stunning lack of astronomy knowledge of the new Harvard graduates.

According to the ASSCI research study, twenty-one out of twenty-three students and alumni gave incorrect responses to the questions asked by the researchers. Topics covered involved seasons, moon phases, and the circular degree of the Earth's orbit. These misconceptions illuminated the fact that even educated Ivy League graduates were poorly educated in astronomy, failing to exude the most basic truths about various basic astronomical concepts. In one instance, a new Harvard graduate that was interviewed in the documentary incorrectly stated that the changing orbital distance of the Earth is responsible for the seasons we experience. This is clearly false, as the seasons are a result of the amount of direct sunlight the Earth receives, varying from the northern hemisphere to the southern hemisphere with changes particularly more apparent during the summer and winter solstices, not forgetting the vernal and autumnal equinoxes.

CHAPTER III

METHODS

In designing my experiment, I followed a framework that best suited my procedure and executed each step of my methodology despite imposed constraints on the acquisition of my survey instruments and my data collection capability. When implementing my concept inventory surveys to the student volunteers involved, I initially met only half of the quota of volunteer data due to impeded communication. The second half of my volunteers responded after a period of three to four weeks. The COVID-19 virus, a lack of communication with the concept inventory distributer and the medical circumstances of another concept inventory creator that was physically ill and unable to contribute to this project were hurdles that impeded my work. These issues delayed my progress, however, after searching through an online assessment repository, I found new options, and was able to progress.

The method I used to distribute the assessment surveys was primarily through contact with the course instructor. There were four instructors of the introductory astronomy lab. From each of these instructors, a range of two to six students from each class volunteered. My main goal was to ensure that proper attention was given to the fair and equal treatment of all participants for superior accuracy and precision of the study, regardless of gender, ethnicity or any other background that did not affect the premise of my survey or that was out of the students' control.

Assessment Management Methods

Searching for the Exam

A concept inventory exam was assigned to non-science major astronomy students in order to measure their basic understanding of the course material. There were initial challenges in finding the appropriate exam for the students due to many different issues including the lack of communication with the test developer. There was one month of unsuccessful attempts to contact the developer, and after the realization that the ASSCI concept inventory could not be obtained, I made the decision to search for and eventual acquire a suitable alternative, the AMS survey. The delay forced me to change my method of conducting a pre-test and post-test three months apart to assigning one survey three quarters through the semester to both groups for a "snapshot" of their condition up to that point through the course.

After searching for other concept inventory exams, I found a concept inventory at *physport.org*, a research-based resource complete with a substantial selection of concept inventories focusing on a vast array of different topics. After searching through the many different topics and categories on the website, I was able to narrow down my choice to three astronomy-based concept inventories. The main contenders for use in my survey were the Star Properties Concept Inventory (SPCI), the Test Of Astronomy STandards (TOAST), and the Astronomical Misconceptions Survey (AMS). After examining each exam, I eventually selected the AMS concept inventory test, due to its relevance to the UTRGV introductory astronomy lab curriculum as well as personal preference.

Finding volunteers

Throughout the initial process of finding volunteers, there were several changes made to who made up the volunteer population. I primarily decided to make the survey volunteers gender equivalent, taking equal numbers of male and female volunteers for both the control and experimental groups. This selection was very difficult to reach due to the larger turnout of female volunteers to male volunteers. I realized that I needed to simplify my search by not specifying the gender of the participants but in making it a non-gender-specific survey.

There were a few challenges to my study involving the sixteen AMS volunteers, however, keeping in timely communication with them was the greatest challenge. I quickly learned that the astronomy volunteers had various commitments and projects that took precedent to my survey. Due to this, there was a delay in my data flow, and this caused a delay and a great inconsistency within my procedure and timing. To manage this inconsistency, I made a change to my approach in the distribution plan and methodology of the surveys.

Astronomy Assessments

AMS and TOAST Surveys

I based my study on two concept inventory exams. The first exam is called the Astronomy Misconceptions Survey (AMS). The second is called the Test Of Astronomy STandards (TOAST). For the AMS survey, the data obtained from that survey was used directly in my analysis, while the supplementary TOAST "benchmark questions" was used to add consistency to the AMS survey for each student. The survey data received from the volunteers was compared to the answers in the TOAST survey done years prior by a group of 253 university students and was then further analyzed.

The "benchmark questions" mentioned are three of twenty-seven carefully selected TOAST survey questions from that concept inventory exam. Based on the results of the TOAST survey of 253 university students, there was a measure of difficulty and discrimination of each problem. My personal use for the selected survey questions was to measure and compare the standings of the UTRGV Astronomy students of both Legacy and CTMO curricula to the data published in the TOAST experiment of the 253 volunteers. In the corresponding TOAST publication detailing the results of this survey, there was a thorough analysis of the student performance and decisions made on each of the twenty-seven questions in the survey. I looked only at the three questions that were relevant to my study which were selected beforehand.

Astro Teacher Survey (SATA)

Within a week of formulating my survey, I received data from the instructors who taught the labs of my selected student volunteers. This data, from the instructors, was a 34-question survey titled "Survey of Attitudes Towards Astronomy," based on a five-point Likert scale. The premise of this survey was to provide a measure of each teacher's interest in astronomy with the goal of determining how interested and effective the teacher was at instructing the lab throughout the semester. This was done mainly to help improve the relevance and accuracy of the overall survey. Within a week of formulating my survey, I received data from the instructors who taught the labs of the student volunteers. This data from the instructors was a 34-question survey titled "Survey of Attitudes Towards Astronomy," with answers based on a Likert scale of one to five. The purpose of this survey was to provide an effectively gauge of each teacher's standpoint towards astronomy to determine how knowledgeable and potentially effective the teacher was during instruction of the lab throughout the term. The purpose of conducting this by the enrolled student population.

Project Timeline

The duration of my functional work from acquiring my survey material and data to the end of my project is approximately ten months. The project officially started in February during the 2021 Spring semester and completed the project at the end of the Fall semester in November 2021. I also worked throughout both summer sessions in between the two semesters searching for and developing the teacher surveys.

At the start of the new year, in January, I began to develop my methodology as well as plan the acquisition and distribution of the relevant surveys. The focus was to measure the efficacy of the CTMO curriculum and compare it to the Legacy curriculum, albeit without fully understanding how to do it. In February, I reached out to the ASSCI creators at the Harvard-Smithsonian in hopes of acquiring their Astronomy and Space Science Concept Inventory exam to use as my main instrument in my project. Due to lack of two-way communication between myself and the survey creator, the exam was unattainable, causing a change in my approach from a pre and post-test exam to a summative assessment, a one-time snapshot of student progress after most of their coursework was completed towards the end of the Spring semester.

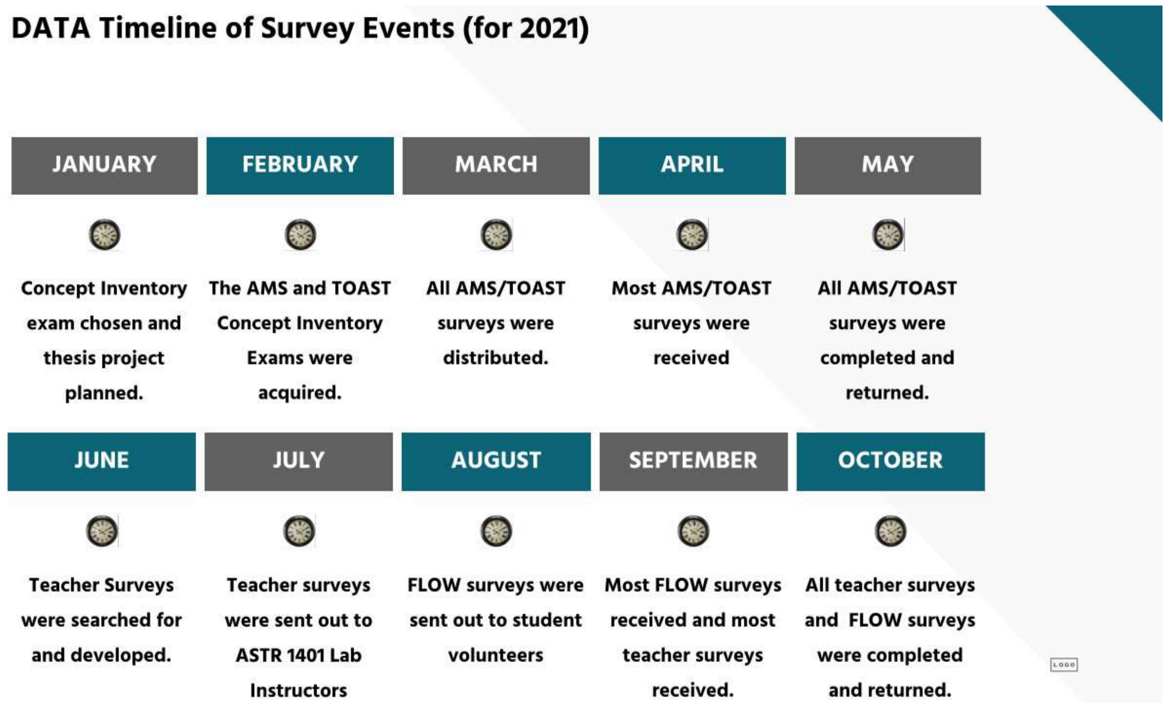

Figure1: Project Timeline

CHAPTER IV

RESULTS

I obtained my results through data gained purely through online methods due to constraints and limitations caused by university policy as well as convenience and practicality of operation. My data consists of survey and questionnaire responses that were answered by multiple respondents including both students and teachers. My collected data is composed of two teacher surveys and three student surveys. The surveys comprise the following:

All data instruments used in my study:

(1) AMS Concept Inventory Exam

(2) TOAST (Test Of Astronomy STandards) Survey Benchmark

(3) Student Flow Survey

(4) SATA (Survey for Attitudes Towards Astronomy) for teachers

(5) Teacher Evaluation Survey

The first survey used in my study was the Astronomy Misconceptions Survey (AMS) which was sent to eight CTMO lab volunteers and eight Legacy lab volunteers. This survey was structured to address basic astronomy concepts such as stars and planets, ring systems, gravity, waves, eclipses, phases, and temperature. These were the main topics spread out across 25 total questions that made up the survey. The questions in the survey were slightly challenging, but the content was information the students should have covered throughout their primary and secondary schooling. Concept inventory exams are meticulously crafted by dedicated researchers over the course of many months to years and are closely guarded to preserve the accuracy of the results produced by that assessment. Due to the difficulty of developing these exams, the exam distributer only gives out tests by request and does so on a conditional basis. This condition states that the exam receiver will not share the answer key online or elsewhere to protect the test instrument's integrity. At the physport repository, where I received the AMS and TOAST instruments, this was the only requirement that was strongly enforced. This commitment procured the exam for any of the uses for my thesis, however, an agreement to these conditions was required to have access to any of the instruments in the repository.

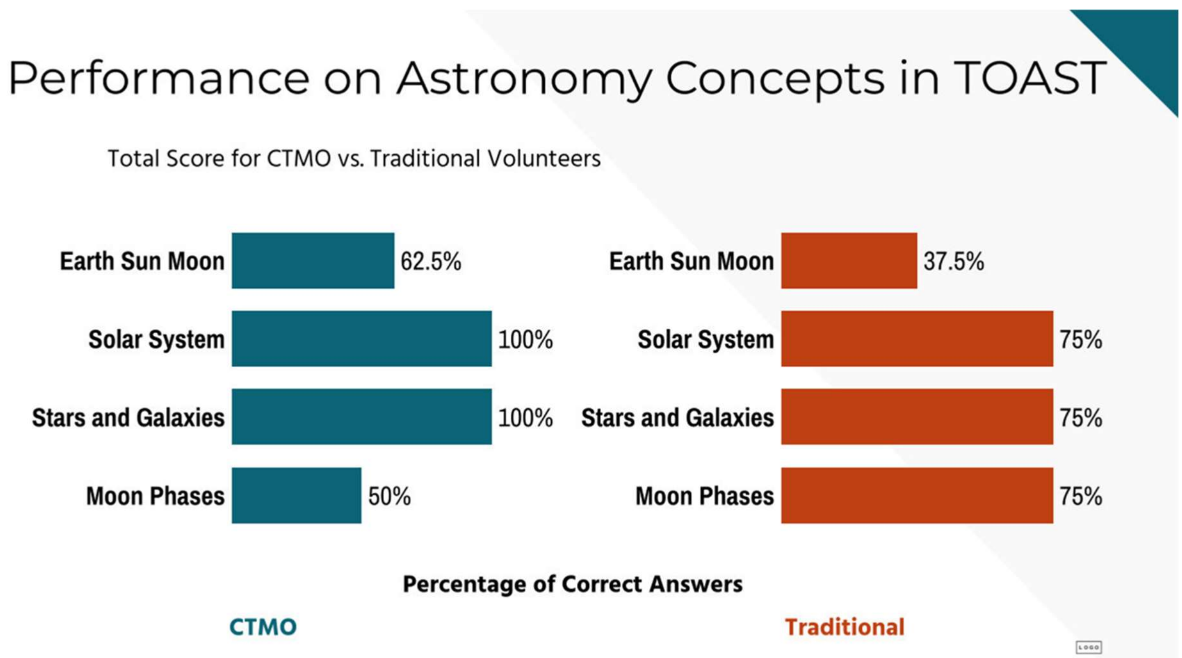

Figure 2: Conceptual TOAST Results

Table 1: AMS Toast and Flow Data

Volunteer ID	Lab Group	AMS Score %	TOAST Benchmark Score %	Flow Rating 1 to 5
1	CTMO Lab Group	52%	66.7%	2.00
2		40%	33.3%	4.67
3		68%	66.7%	2.67
4		44%	66.7%	4.00
5		28%	100.0%	N/A
6		64%	66.7%	N/A
7		68%	66.7%	N/A
8		52%	66.7%	3.67
9	Traditional Lab Group	48%	66.7%	3.33
10		48%	66.7%	5.00
11		48%	100.0%	4.33
12		76%	100.0%	N/A
13		32%	0.0%	N/A
14		52%	66.7%	3.67
15		52%	33.3%	4.00
16		40%	66.7%	3.00

For the teacher attitudes towards astronomy survey, I used an assessment developed by an astronomy professor from the University of New Mexico titled the Survey for Attitudes Towards Astronomy, or SATA. By using this assessment, I was able to quantitatively measure the varying levels of interest in astronomy that was held by all teachers involved in my study. The survey was designed to measure general attitudes towards general astronomy concepts quantitatively through a thirty-four-question survey.

Table 2: SATA Teacher Survey Data

Teachers	Strong Negative Response (1)	Negative Response (2)	Neutral Response (3)	Positive Response (4)	Strong Positive Response (5)
Teacher 1 CTMO	1	5	8	5	15
Teacher 2 CTMO	1	6	4	10	13
Teacher 3 Traditional	4	2	2	2	24
Teacher 4 Traditional	5	1	6	6	16

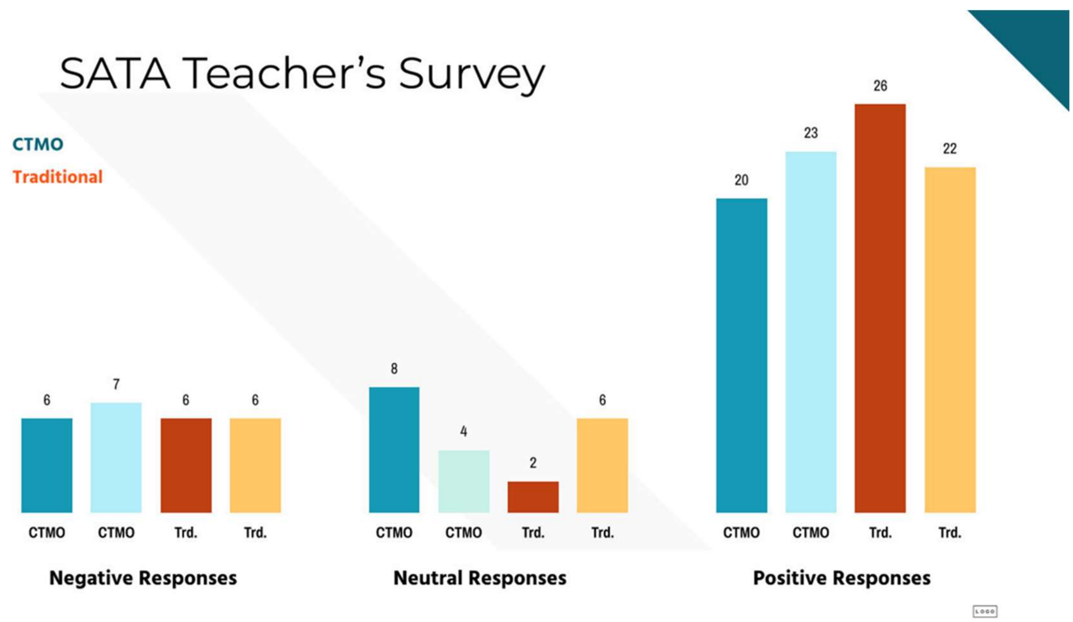

Figure 3: SATA for Teachers Results

Comparison of Difficulty for UTRGV and TOAST Studies

Item	TOAST Study	CTMO	Traditional
Item 3	57%	50%	75%
Item 8	43%	63%	38%
Item 11	60%	100%	75%

Figure 4: Average TOAST Results

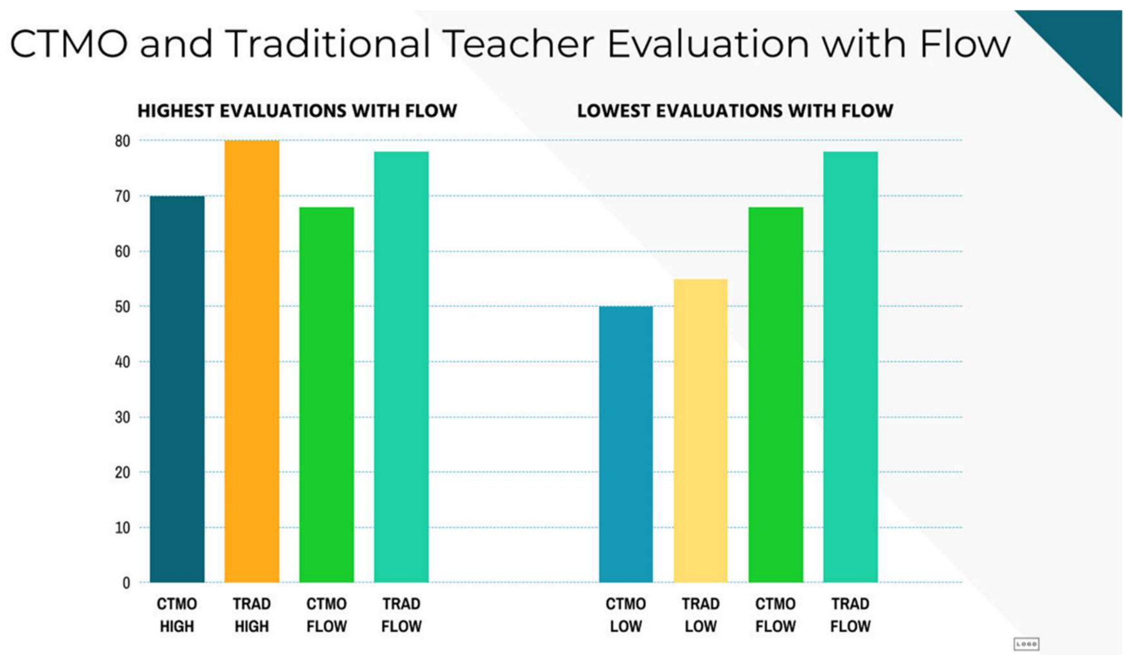

Figure 5: Teacher's Evaluation and Flow

Table 3: Student Survey Results

AMS, TOAST, & FLOW SURVEY RESULTS

Students	Test	Items	N participants	Mean	Rating
CTMO	AMS	25	8	54.5%	CTMO
Traditional	AMS	25	8	49.5%	Traditional
CTMO	TOAST	3	8	66.7%	CTMO
Traditional	TOAST	3	8	62.5%	Traditional
CTMO	FLOW	3	5	3.4/5	CTMO
Traditional	FLOW	3	6	3.9/5	Traditional

Table 4: Non-parametric Test for AMS

	A	B	C	D	E	F	G	H
1	Curriculum	AMS Scores	RANK					
2	CTMO	52	10.5					
3	CTMO	40	3.5					
4	CTMO	68	14.5			Sum of Ranks	Count	U Statistic
5	CTMO	44	5		CTMO	72.5	8	36.5
6	CTMO	28	1		Traditional	63.5	8	27.5
7	CTMO	64	13					
8	CTMO	68	14.5		Critical Value	13		
9	CTMO	52	10.5					
10	Traditional	48	7					
11	Traditional	48	7					
12	Traditional	48	7					
13	Traditional	76	16					
14	Traditional	32	2					
15	Traditional	52	10.5					
16	Traditional	52	10.5					
17	Traditional	40	3.5					
18								

Table 5: Non-parametric Test for TOAST

	A	B	C	D	E	F	G	H
1	Curriculum	TOAST Scores	RANK					
2	CTMO	66.7	8.5					
3	CTMO	33.3	2.5					
4	CTMO	66.7	8.5			Sum of Ranks	Count	U Statistic
5	CTMO	66.7	8.5		CTMO	68.5	8	32.5
6	CTMO	100	15		Traditional	67.5	8	31.5
7	CTMO	66.7	8.5					
8	CTMO	66.7	8.5		Critical Value	13		
9	CTMO	66.7	8.5					
10	Traditional	66.7	8.5					
11	Traditional	66.7	8.5					
12	Traditional	100	15					
13	Traditional	100	15					
14	Traditional	0	1					
15	Traditional	66.7	8.5					
16	Traditional	33.3	2.5					
17	Traditional	66.7	8.5					
18								

Table 6: Non-parametric Test for Flow

	A	B	C	D	E	F	G	H
1	Curriculum	Flow Scores	RANK					
2	CTMO	2	1					
3	CTMO	4.67	10					
4	CTMO	2.67	2			Sum of Ranks	Count	U Statistics
5	CTMO	4	7.5		CTMO	26	5	11
6	CTMO	3.67	5.5		Traditional	40	6	19
7	Traditional	3.33	4					
8	Traditional	5	11		Critical Value	3		
9	Traditional	4.33	9					
10	Traditional	3.67	5.5					
11	Traditional	4	7.5					
12	Traditional	3	3					
13								

Table 7: Critical Value Table at 5% Alpha

	A	B	C	D	E	F	G	H
1		**2**	**3**	**4**	**5**	**6**	**7**	**8**
2	**2**							0
3	**3**				0	1	1	2
4	**4**			0	1	2	3	4
5	**5**		0	1	2	3	5	6
6	**6**		1	2	3	5	6	7
7	**7**		1	3	5	6	8	10
8	**8**	0	2	4	6	7	10	13
9								
10								

CHAPTER V

DISCUSSION

Since the early 1990s, robotic telescopes have achieved substantial gains in research, education, and outreach. One way this was achieved was by leveraging breakthroughs in technology and converting existing manned observatories into purely robotic ones. This approach has grown exponentially up until today and it has had an impactful long-term effect on astronomers and students who have conducted observations throughout the decades. The first fully robotized observatory was a facility at the University of Wisconsin operating an eight-inch reflector telescope during the mid-1960s. Over the decades, many more robotic observatories have been established, such as the Faulkes Telescope project which is one of the largest in the world. Within the next few years, the Vera Rubin Telescope should become available, with an ambitious mission of creating a motion picture of the universe by taking images of the total night sky consistently for a ten-year period. This is only the beginning of robotized astronomy.

Astronomy and CTMO

CTMO Defined

The Cristina Torres Memorial Observatory, known by UTRGV astronomers as CTMO, was inaugurated on May 6th, 2018 at the Resaca de la Palma State Park. Since then, there have been numerous upgrades to the facility. Some early technological improvements were solely digital, while our most recent achievements have been structural. For instance, within the first few months of inauguration in 2018, there was a significant breakthrough with our internet capacity, allowing for a Wi-Fi connection in the dome. Two years after inauguration, in 2020, we began upgrading our facility, allowing for environmental controls. This was a critical component due to the infestation of harmful parasites that plagued the facility throughout its operation, disrupting the observers and detracting from the data collection process.

The Cristina Torres Memorial Observatory is primarily a research platform. However, it also incorporates outreach and education activities throughout the year. The outreach conducted consists mainly of monthly astronomy observation nights open to the public for a small fee. The main event is the night-time hike across one of the park trails at dusk. After dusk, when the hike is complete, hikers have the option to stay and participate in an observation free of any additional charges. The observation can be anything visible in the sky such as different planets and moons to satellites flying overhead if the weather conditions permit. The total observation time of the event ranges from twenty minutes to an hour of hands-on activity. There is, however, a line for the observers of each telescope with a total of three or four operational telescopes throughout the night. This means three to four attendees are observing at any given time. Although this may seem like an inconvenience, a CTMO astronomer volunteer is responsible for showing the visible constellations to attendees waiting to view through the telescope equipped with admired green astronomy lasers which generate added interest for the observers and keep the night entertaining for adults and children alike,. History and lore are also recited, elucidating the ancient views and interpretations of the cosmos, also an effective part of the experience.

The scientific merit achieved by the CTMO facility is significant with regards to the arena of multi-messenger astronomy. CTMO is a capable research tool with collaborations with LIGO (Laser Interferometer Gravitational Wave Observatory), Texas A&M, and TOROS (Transient Optical Robotic Observatory of the South) to name a few. One instance of the significant achievement accomplished by the observatory is when CTMO and the TOROS Collaboration conducted optical follow-ups during the advanced LIGO VIRGO O2 second observational campaign. The main objective was to use the observatory to find optical counterparts to known recent gravitational wave events. With a field of view of 100 arc minutes, CTMO was able to attempt to localize the source of the gravitational wave event. Random forest algorithms were used to discriminate between real and false transient events. Other observatories also worked in tandem with CTMO through participation in the LIGO optical follow-ups.

New Innovations at CTMO

The traditional ASTR 1401 Introduction to Astronomy curriculum is somewhat effective at educating non-science majors, however, the form and structure of the curriculum is not as current as the more innovative Karplus learning cycle based CTMO version. Many problems astronomy educators currently face can be overcome by applying advances in recent technological developments, and CTMO curriculum has taken this approach by aiming to robotize its operations. A portion of the innovative CTMO labs is based on robotization of the observatory, giving astronomy students direct control of the telescope and making data acquisition possible from the student's current location regardless of physical distance. This means that operations can be carried out without the observer physically being present at the observatory. This is done through an internet connection and the K Stars software, allowing full access to the telescope. Currently, the observatory is not robotized and has only completed trial runs with lab students, however, this capability is in development for application within the next few years. By making CTMO a fully robotic observatory, astronomy students can avoid many of the issues that are prevalent in conducting an observation, such as maintaining an average daytime schedule while observing at later hours of the night. Also, the complexities of transportation cause students to potentially miss out on a target opportunity in the night sky. This makes access to robotic facilities which can be done virtually from any computer with an internet connection possible, and the observatory would follow this objective as well. The role CTMO and other robotized observatories play mitigate the inconveniences of traveling to sites usually outside city limits with a low level of light pollution. It should be mentioned that operating a robotic telescope lowers expenses for students and astronomers by mitigating travel expenses and time away from home that would otherwise be required to physically visit an observatory at a distant location during late hours. Robotic telescopes present a strong advantage due to this, making them a viable way for undergraduate astronomy students to have a positive learning experience.

Data Acquisition

Due to the COVID-19 pandemic which occurred throughout the Spring 2021 Semester during my study, standard procedures were strictly mandated throughout the UTRGV campus. This warranted the need for more stringent protocols and added constraints on the day-to-day functions and activities. This included quarantine procedures for all faculty, students, and staff who tested positive for the virus or had returned to the Rio Grande Valley after being out of the region for a prolonged period. There were also various other mandates and restrictions put into effect which impeded data acquisition. The operations of the CTMO facility were also affected by COVID-19, which significantly slowed research and shut down most observations throughout the 2021 Spring semester and Summer sessions.

CHAPTER VI

CONCLUSION

In a ten-month span from January 2021 to November 2021, student volunteers were selected to have their astronomy knowledge anonymously measured and documented for my conceptual understanding of educational methods thesis. Evident problems along the way appeared due to challenges from online communication as well as from a global pandemic. Mitigating the delays and shortcomings throughout my project timeline was challenging, however, with the assistance of key individuals, I was able to complete my work without significant delay.

Research Objectives

The volunteers involved in my study contributed to the findings of astronomy labs based on the Karplus learning cycle through their participation in the five surveys and questionnaires assigned to them. The purpose of my research was to understand how students from different curricula compare with one another in knowledge as well as understand their general interest in astronomy based on the input acquired from three assessments. The instructors of these student volunteers were assigned surveys as well. Two surveys given to the student volunteers' lab instructors were used to determine their basic attitudes towards astronomy and confidence level towards their students.

In the data I received, there was strong indication that the CTMO lab curriculum was a more effective approach to teaching astronomy than the Traditional lab curriculum. To verify the accuracy of the results, I implemented a Mann-Whitney U Test on the three student survey results. After performing the tests and analysis, these surveys, the AMS, TOAST, and Flow surveys all remained valid after results supporting that the null hypothesis was rejected were confirmed. This means that there was a definite relationship between the two phenomena. The critical value for my survey was calculated to find the relationship between itself and the U statistics. It was determined by finding the count of entries for the experimental and control data points obtained through the U-test. In finding the U Statistics for each variable, I was able to compare them both and determine the degree of coincidence in ranks between the two groups of variables. For the AMS, TOAST, and Flow Surveys, the calculated p-value was greater than 0.05 which meant that there was no overlap present in my analysis, and I accepted the null hypothesis, meaning there is no significant difference between populations.

This study has shown that the performance of students taking the CTMO curriculum surpassed the performance of those taking the Traditional curriculum. This was determined using the AMS and TOAST Survey Assessments. It was found that the CTMO group performed higher on the TOAST and AMS assessments by margins of 4% and 5% respectively. Also, in the Flow assessment, there was a margin of 10% with the Traditional group leading CTMO. My hypothesis of a more favorable flow rating for CTMO was incorrect. My original goal was to have a sample size of 30 student volunteers per group, however, this number became 8 students per group with 16 total students in both groups due to the lack of available volunteers. Consequently, I used the Mann-Whitney U Test as an alternative to the T test to improve the accuracy of my results and to better interpret them while working with a small population size.

Due to the distribution of values, a non-parametric U Test was preferred over the T test, and by calculating the U statistic through excel, I compared the ranks of the two measured values, defined as the CTMO and Traditional survey scores. From this new information, I found that with a P-value of greater than 5%, there was no statistical significance. In words, there was no difference between the two means, which implies that the null hypothesis was zero in the case of all three parametric tests for the three assessments.

Solutions to Major Challenges

My Solution to Communication Difficulties

On multiple tasks, communication was a major challenge for the efficient progress of my thesis. Initially, I planned a large-scale volunteer operation. Due to lack of communication and availability, this number was halved. In my study I used sixteen student volunteers and the four astronomy instructors of those students. During early March, all the volunteers received my survey and were given instruction to return them in one week. This led to the immediate response of only two students, possibly due to a missed email or being unable to comply at that moment. The method I used to get around impeded communication involved reaching out to all dormant volunteers through email. I sent a minimum of ten messages to all non-responsive students throughout a two-month period for my AMS and TOAST surveys and I sent about twenty emails to professors from other parts of the country whose research contributed to my thesis. In total, a large quantity of emails, over 200, was sent out to all parties. Many of these emails were sent multiple times while eventually receiving a reply, but this action was necessary to communicate with many of the volunteers that were harder to reach.

My Solution to SATA Survey Challenges

To increase the accuracy of my study, I incorporated a test to quantitatively measure teacher interest and attitudes towards astronomy. I accomplished this through the Survey of Attitudes Toward Astronomy exam. The SATA instrument was created by a professor from the University of New Mexico in the 1990s. I visited his website called the Field-tested Learning Assessment Guide (FLAG) and searched through various astronomy test instruments. I decided on the SATA for its focus on discipline, purpose, and technique towards astronomy and its relevance to the data I needed for my study on teacher interest in astronomy. I acquired the exam and was able to send it to the instructors of the students who I surveyed with the previously used AMS concept inventory exam. My setback mainly had to do with the grading of the exam itself. I acquired the survey, but I did not have the answer key to score the survey. Due to the age of the website and the instrument, the solutions could not be obtained, as the FLAG website had some inoperative hyperlinks, blocking access to the answer key. After sending multiple emails to the SATA survey creator, I did not receive any response from him for approximately two months. This contact was necessary for me to acquire the SATA survey answer key. The key was crucial, as I would not have a straightforward way to interpret my survey data. After two months, I received a follow-up email from a woman related to the survey creator that had managed his social media accounts. I was told that the researcher was medically ill and was in no capacity to continue his work at the time, which resulted in a dead end for my acquisition of the assessment key. She sincerely informed me that, regrettably, there was nothing she could do relating to my research goals which my overall thesis depended on. I gracefully moved on and made the effort to decipher the SATA survey results through generalizations and intuitive means of my own based on research and the resolve of sound scientific thought. After days of sorting through the survey, I was able to receive accurate data from the survey that resulted in relevant data for the SATA study which was then applied to my thesis.

My Solution to the COVID-19 Pandemic

The greatest challenge throughout all my operations was the Coronavirus pandemic. This prompted lockdowns generated and complications throughout every aspect of my research. At the university level, research slowed drastically, and my contacts became more difficult to communicate with. Because of national, implemented stay-at-home measures put into place, there was no plausible way to physically meet with any of the volunteers that were part of my survey. All operations were solely carried out through online means without any physical contact with anyone in person during the semester. This also took much longer due the compromised availability of the student volunteers and their home situations which created inconveniences for my study. Student availability was a concern for me and due to COVID, all priorities had shifted to basic health and wellbeing standards regardless of any academic gains that were or were not made, making prioritization of my requests much lower than it would have been pre-pandemic. Unfortunately, the shift was against the course of my study, causing an erratic return time of the surveys sent out to the volunteers. To fix the complications incurred in the post-COVID world, I adjusted my aim and intentions to better suit the project in a more productive way. Circumventing my original plan was troublesome, however, suitable alternatives were found, which allowed me to complete my project. The methods I used to manage COVID regulations involved intensive online influence towards research professors, colleagues, and volunteers.

Future Work

Future work could be conducted on any of the three surveys, although the Flow survey has greater potential. By increasing the population size and expanding the scope of subject being taught, a more comprehensive study could be conducted, determining which subjects or curricula may need modification or innovation with the goal of improving student output and knowledge retention. To summarize, the CTMO scores for AMS and TOAST were superior to Traditional scores while the Flow survey scored higher among Traditional students when compared with the CTMO students. Teachers performed well on their questionnaires with greater results on the Traditional side. Unequivocally, the CTMO curriculum is more effective at educating students to take a more active approach towards the process of learning, while the Traditional method, although received more favorably by the students, is obsolete in its implementation and design.

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APPENDIX

APPENDIX

Universal Perspective Astronomy Lab

Developed by: Wahltyn Rattray

Materials:

1. Celestial globe (optional)
2. Computer with *Stellarium* software
3. *NASA's Eyes* free online app
4. CTMO telescope access (optional)

Part 1: Background

Finding our place in the cosmos is a part of what makes us human. It can be a rewarding and intriguing experience for any who choose to pursue it, but the universe can be elusive and difficult to understand at times. The purpose of this lab is to develop and use the skills necessary to first take a 2D approach of objects in space and then expand to a 3D representation using the same objects in space employing a different perspective. Whether using a top-down, or bottom-up view, anyone can train himself to internalize and mentally map out the layout of the sky, solar system, and galaxy.

To scientifically and objectively find one's place in the universe, a few basic concepts must first be understood. We must discuss the celestial sphere, which is the complete view of the night sky as viewed from any location on Earth. By understanding the orientation of the rotating Earth along with the celestial sphere, the North Star (Polaris) can be identified. This is useful since, by measuring the angle relative to the horizon, the declination of the observer at the present location can be known. The knowledge of one's place within the cosmos can be obtained throughout a variety of methods. One way to do this, or understand how the Earth and the astronomer essentially fit into the grand scheme of things, is to study the ecliptic plane, celestial sphere, and various sky objects ranging from stars to planets.

The **ecliptic plane** is a two-dimensional region of space that extends throughout the universe and has the capacity to nearly localize and describe the general position of nearly every planet in the solar system. More simply, the ecliptic is the path that the sun follows against the background of the stars in the night sky. Knowing where the ecliptic plane is in the night sky is a useful and powerful skill which can be used to orient oneself with the celestial bodies and the orbits of many objects in the solar system. In this lab we will use prior as well as newly obtained knowledge to develop an intuitive and pragmatic vision of where and how to know where the ecliptic plane is and what objects lie near it for any given astronomical observation.

A celestial globe is claimed to be one of the oldest tools in astronomy. It is similar to a star chart, but it represents the celestial sphere in a three dimensional form, similar to a terrestrial globe of the Earth. Apart from the 3D representation, all the information is the same as the two-dimensional sky chart, however there is no distortion as there would be on a rectangular map. This relationship between a star chart and a celestial globe is analogous to a world map of the Earth and a terrestrial globe, but instead of longitude and latitude, a celestial globe is read in **right ascension** and **declination**. Reading this celestial globe, however, may seem unnatural since the viewer looks down at the entire sphere as opposed to looking up at the night sky from a vantage point on the earth, but the globe is essentially designed to model the celestial sphere as if it were viewed from within the globe itself, providing a straightforward and simple tool to use once the astronomer is familiar with it.

Stellarium is an astronomy program that allows the user to locate any known object in the night sky at any given time and place within the celestial sphere. It displays those objects to scale with the celestial map and gives the user access to data pertaining to the object of choice. With the "time travel" feature, Stellarium can predict the locations of all celestial bodies in space and time with pinpoint accuracy, providing a means to effectively plan an observation with a high degree of certainty of knowing exactly where to look in the night sky.

The Cristina Torres Memorial Observatory, or CTMO, is a research astronomical observatory located at the Resaca de la Palma State Park near the outskirts of town in South Texas. This area has very little light pollution relative to the surrounding city, making it an ideal setting for observations of the night sky. Inaugurated in May of 2018, CTMO has been the location of constant, daily research and numerous public outreach events. UTRGV Astronomy students will soon have the option to collaborate and conduct robotic telescope operations with CTMO under the supervision of a skilled astronomer.

In this lab we will also be studying and utilizing the ecliptic line. This ecliptic line, or equivocally the ecliptic plane, is an imaginary extension of the sun's equator that stretches off infinitely into space in congruity with Earth's orbital plane. The planets follow this line as they traverse the solar system in their orbits. It is called the ecliptic line primarily because eclipses viewed from Earth take place along this line in space. It is also apparent that all the astrological constellations lie on the ecliptic. This is due to the fact that the Earth's orientation relative to the sun and these constellations allows for them to be seen at the same location every orbit, or 365-day period.

It is necessary to note that in the days of Copernicus, orbits were thought to be completely circular. It took years before Johannes Kepler presented his famous three laws of planetary motion. Because of the fact that planets orbit in ellipses, the speed of the planets varies throughout their orbits. Kepler's three laws of planetary motion state:

1) Planets orbit in an ellipse with the Sun at one of the two foci.

2) The line segment joining the planet and the Sun sweep out equal areas in equal times.

3) The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

When referring to a star's or planet's inherent brightness, we are speaking of how bright that star is in a logarithmic magnitude scale. The magnitude formula that takes into account apparent magnitude and absolute magnitude of a star is as follows. If Jupiter and Saturn are close together in the night sky during an observation, the astronomer can identify which is which by knowing the relative albedo, or percentage of reflected sunlight. This will provide the information necessary to gauge which planet in the sky is which by taking note of which source is brighter and matching that data with what you obtain from actual observation. This can be of great use when multiple planets are close together in the night sky.

Table1: Orbital Data on Four Brightest Planets and Earth

Planet	Orbital Eccentricity (ε)	Inclination of Orbit to Ecliptic (°)	Inclination of Equator to orbit (°)	Albedo (%)
Venus	0.007	3.39	177.3	0.65
Earth	0.017	0.00	23.45	0.37
Mars	0.093	1.85	25.19	0.15
Jupiter	0.048	1.31	3.12	0.52
Saturn	0.054	2.49	26.73	0.47

Planet: The four brightest planets along with the Earth are listed here. These four planets are visible from Earth on a clear night throughout different parts of the year.

Orbital Eccentricity is a measure of how circular or elliptical an orbit is. This eccentricity can explain why planets move slower in their orbit at some times and faster in their orbit at other times.

Circular orbit: $\varepsilon = 0$

Elliptical orbit: $0 < \varepsilon < 1$

Parabolic orbit: $\varepsilon = 1$

Hyperbolic orbit: $\varepsilon > 1$

Inclination of orbit to ecliptic is the angle the orbital plane makes with the ecliptic plane.

Inclination of equator to orbit is the tilt of the planet's axis relative to the ecliptic.

Albedo is the percentage of sunlight that is reflected by a planet moon or asteroid. The higher the albedo, the brighter the planet appears.

Part 2: Lab Activity – Developing a Cosmic Perspective through Astronomy Tools and Software

Section A: The visualization of our Solar System and Milky Way Galaxy

The view of the solar system is provided here to show the scale of the planets and the sun.

The Solar System with unscaled distances.

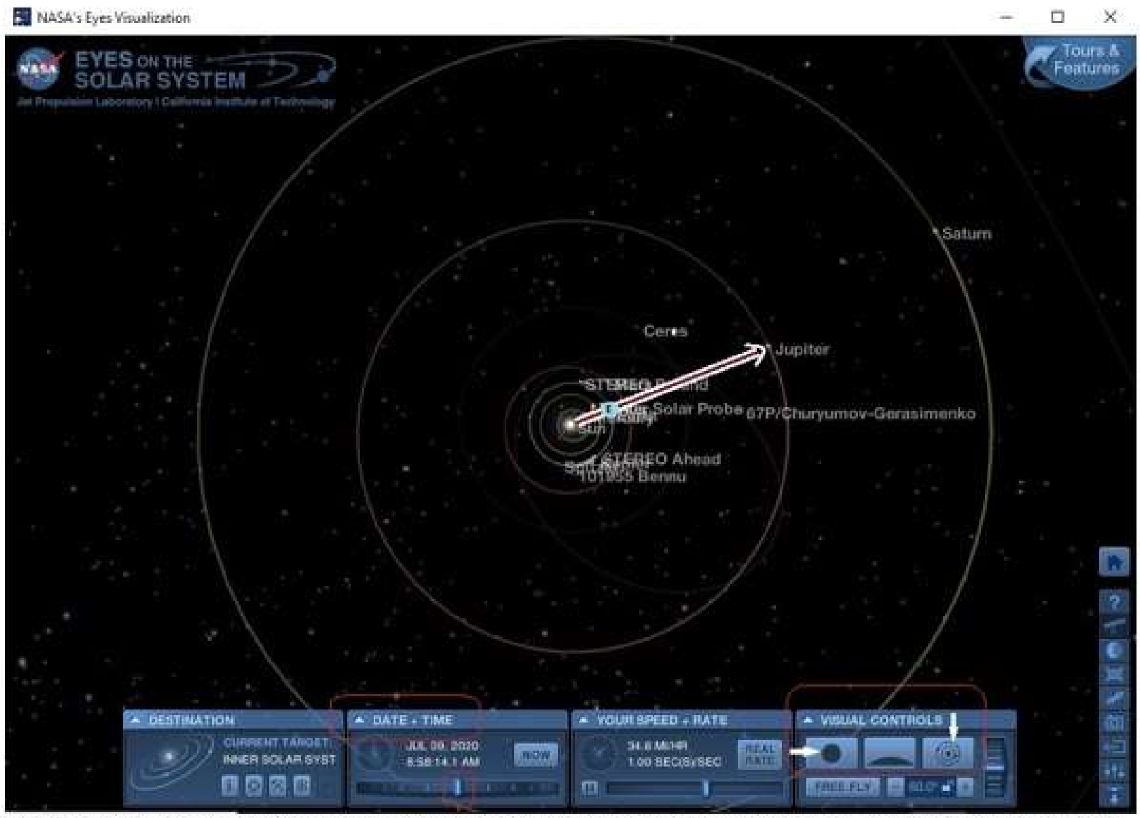
Section B: NASA's Eyes (an "outer" perspective)

<u>Installing the NASA's Eyes app</u>

1) Enter https://eyes.nasa.gov/ into the URL.
2) Click the "Download the App to Get Stared" button.
3) Click on the executable file to install the NASA's Eyes app.

<u>Navigating the NASA Eyes app</u>

1) Open the NASA's Eyes app
2) Click on Eyes of the Solar System
3) Use the zoom command and zoom in and out to view the solar system. When looking towards the sun and inner solar system, zoom in. When looking outwards towards the outer solar system, zoom out.



NASA's Eyes example of exercise with superimposed red and white arrow. Earth is at occultation with Jupiter on July 9th, 2020 (using the time travel feature).

The purpose of this activity is to visually understand the orientation of the Earth and planets during a planetary occultation by viewing the solar system in two dimensions. When a planet is at occultation when viewed from Earth, it is colinear with Earth and the Sun. Remember, the night side of the planet always faces away from the Sun, and the observer is pointed away farthest away from the sun at midnight.

1) Open the NASA's Eyes app.

2) Under "Eyes of the Solar System" click "advanced"

3) In your head, draw an imaginary straight line between the Earth and the sun with the start at the sun, extending outwards through the solar system on the map (as seen in Figure 2). This is more of a visualization technique. You do not need to physically draw anything out. Only the orientation of the Sun, Earth, and outer planet is relevant here.

4) With the "Visual Controls" command, you can zoom in or out with the buttons indicated above with the two white arrows. The button on the left zooms in while the one on the right zooms out. To pause time, click on the "pause" button in the "Your Speed + Rate" window.

5) Use the date and time slider to travel forwards or backwards in time. The purpose of this is to speed through the planetary orbits until Earth the sun and an outer planet are aligned.

6) Write down the date and time of the planetary alignment, or occultation, visible in the Date and Time box.

7) Do this for two planets anywhere outside the orbit of the Earth towards the edge of the solar system.

8) Close NASA Eye's app. Be sure to *note the date and time* of these alignments, as they will be necessary for the next part of the lab.

Section C: Stellarium (an "inner" perspective)

<u>Installing Stellarium</u>

1) Open your browser and type in <u>stellarium.org</u> in the URL.

2) Choose latest version of Stellarium based on your choice of operating system.

3) Choose a language.

4) Follow through and complete the Stellarium setup wizard

5) Once finished, open the program by clicking on the Stellarium icon.

<u>Configuring Stellarium Viewing Options:</u>

1) Open Stellarium.

2) Mouse over to the lower right hand side to access the pop-out sidebar

3) Click on the "Location window."

4) Type in the coordinates for the telescope location (Brownsville, TX: Latitude: N 25º 55' 48.00" Longitude: W 97º 28' 48.00" Altitude: 8 meters.

5) Close “Location window”

6) Open the “Date/time window.”

7) Enter the appropriate date and time of the potential observation.

8) Close the “Date/time window.”

9) Open the “Sky and viewing options window.”

10) Click the “Markings” tab.

11) Under “Celestial sphere” check the “Ecliptic line” and “Azimuthal Grid” boxes.

12) Under “Projection” select the “Perspective” viewing mode to clearly see the ecliptic line and night sky exactly as they appear in reality.

13) Under “Constellation” select the “Show lines” and “Show labels” box.

14) Close “View” window.

Figure 7: A view of Jupiter in the Stellarium sky

<u>Stellarium Activity</u>

The purpose of this activity is to understand how objects in the night sky move over time when they are viewed from a consistent location and vantage point on Earth in three dimensions. Using Stellarium, we can emulate future sky-target conditions and also generate accurate *predictions of the locations of the planets of the solar system, the moons, and the stars. Follow the steps below and complete the subsequent section.*

1) Open Stellarium.

2) Make sure the program is properly configured using the steps listed above.

3) Open the “Date and Time” window.

4) Enter the previously recorded date from Section B into the window.

5) Find the planet on the Stellarium screen and click and drag to better view the planet (remember to focus your search only along the ecliptic line).

6) The position of the planet in the Stellarium sky can be changed by clicking on the arrows above and below each date and time entry.

7) Change the planet’s orbit hour by hour until the planet is as high in the sky as possible (from the horizon at 0° to the zenith at 90°).

8) Verify that the planet is in the sky after dusk, along the ecliptic or very close to it, and a minimum of 30 degrees above the horizon.

9) Repeat steps 4 through 8 for the second planet you used in Section B.

10) Fill out the following chart and close the program.

Planet	Distance from Earth (AU)	Degrees Above Horizon(Altitude)

Distance from Earth can be found in the top left corner of the screen in Stellarium.

Section C: Making an Observation

If the planets used in Section B and Section C are visible during the semester, the student can proceed with an observation of those planets primarily through a naked-eye observation, or if applicable, through CTMO with the help of an astronomer. This is optional *but quite rewarding.*

Naked-eye Observations

If the students have the opportunity to witness a planetary occultation, then they should schedule a date and time of observation. This should be done on a day of optimal weather and meteorological conditions. At a minimum, observations should officially take place at the end of astronomical twilight, 30 minutes after the sun sets below the horizon. Select a desirable viewing target based on its position and elevation in the night sky. The student's goal is to cognitively map out and orient himself under the stars. The North Pole of the celestial sphere should be identified, along with the ecliptic and, with software, the galactic plane.

Telescope Observations at CTMO (assistance provided by senior astronomer)

1) Check the weather for the observation night and plan observation accordingly.

2) Power up observatory and telescope.

3) Open the dome/shutter.

4) Turn on computer and open software.

5) Pick a target and take images.

6) Save data and power down telescope.

7) Close the observatory

The images taken are for the student to present at a talk or conference or use in whatever way he or she prefers.

Part 3: Lab Questions

1) Why does the North Star remain stationary as the other stars move in a circular pattern in the sky over the course of the night?

2) How is it that two planets viewed from Earth can appear close together in the sky but are actually extremely far apart? How does this general perception relate to parallax?

3) Based on Table 1, which planet has the smallest change in seasons based on its orbital equator inclination? How can you tell?

Use the chart below to answer the following questions.

Star	Spectral Class	Absolute magnitude (M)	Apparent magnitude (m)	Distance from Earth (d) parsecs
Sirius	A1	1.5	-1.4	
Arcturus	K2	-0.3	-0.1	
Vega	A0	0.5	0.0	
Rigel	B8	-7	0.1	
Betelgeuse	M2	-5.5	0.4	

1 parsec = 3.26 light years = 3.09×10^{13} km = 2.06×10^{5} AU

Spectral Classification and Surface Temperature: O - B - A - F - G – K - M

O ≈ 30,000 K	**G** ≈ 6,000 K
B ≈ 20,000 K	**K** ≈ 4,000 K
A ≈ 10,000 K	**M** ≈ 3,000 K
F ≈ 8,000 K	

4) Find the distance of each of these 5 stars from Earth. Use the "absolute magnitude" formula and solve for distance **d** in *parsecs*. () Fill out the chart above.

Formula: $\mathbf{m - M = 5\log_{10}(d/10)}$

Rearranging: $\mathbf{[(m-M)/5] = \log_{10}d - \log_{10}10}$

Rearranging: $\mathbf{\log_{10}d = [(m-M)/5] + \log_{10} 10}$

Remember: $\mathbf{\log_b y = x}$, **so** $\mathbf{y = b^x}$

Solve for ***d.***

5) Compare the distances. Are the stars or are the planets generally closer to the Earth and why? How can you tell?

6) Which star above has the highest surface temperature based on spectral class? Which has the lowest surface temperature?

7) Throughout this lab, you attempted to view the universe with an “inner” perspective with Stellarium and an “outer” perspective with NASA’s Eyes. Which perspective did you find to be most intuitive and why?

Answers to lab questions

1) Why does the North Star remain stationary as the other stars move in a circular pattern in the sky over the course of the night?

This occurs due to the position of the stars relative to the Earth’s rotation about its axis.

2) How is it that two planets viewed from Earth can appear close together in the sky but are actually extremely far apart? How does this general perception relate to parallax?

This is an illusion due to the fact that even though two stars may be far apart, the small angle between them and the relative brightness of the stars makes them seem closer than they are. Parallax helps to overcome this problem by using multiple vantage points known variables to solve for an unknown.

3) Based on Table 1, which planet has the smallest change in seasons based on its orbital equator inclination? How can you tell?

Jupiter has the smallest change in seasons due to its having the smallest tilt of its axis of all the planets in the solar system.

4) Solve for **d**

Distance from Earth (d) parsecs
Sirius ≈ 2.7 pc
Arcturus ≈ 11 pc
Vega ≈ 8.1 pc
Rigel ≈ 265 pc
Betelgeuse ≈ 197 pc

5) Are the stars or are the planets generally closer to the Earth and why? How can you tell?

Since we can see planets change their position in the night sky fairly quickly from night to night relative to stars, they must be closer than the stars. If this were not true, at a distance beyond a certain point from the Earth, they would need to be moving close to or even faster than the speed of light to carry out their journey across the celestial sphere.

6) Which star above has the highest surface temperature based on spectral class? Which has the lowest surface temperature?

Rigel has the highest surface temperature being a B class star while Betelgeuse, an M class star, has the lowest temperature of the stars listed.

7) Throughout this lab, you attempted to view the universe with an “inner” perspective with Stellarium and an “outer” perspective with NASA’s Eyes. Which perspective did you find to be most intuitive and why?

(Subjective question for feedback. Varying response.)

BIOGRAPHICAL SKETCH

Wahltyn Rattray earned his Master of Science in Interdisciplinary Studies after completing his core curriculum and thesis defense in December 2021. His current email address is warattray@gmail.com and it can be used to contact him directly. He is an aspiring science educator with a passion for learning. He considers himself to be a perfectionist with a deep interest in physics and astronomy. From the first time he looked at the moon through a telescope in Canada at the age of three to becoming a research astronomer at the University of Texas Rio Grande Valley in his early twenties, understanding the universe has been his passion and focus. As an aviation enthusiast and musician in his high school years, Wahltyn developed a love for discovery and a zeal for progress in those disciplines that fueled his desire to inquire, all the while embracing the learning process amid the challenges of life. He is compassionate towards others and he stands up firmly for what he believes in. His main goal in life is that, in whatever capacity, he becomes the good that is missing in the world, thus making it a little better tomorrow than it was today.