IMPACTS OF A COURSE-BASED UNDERGRADUATE RESEARCH EXPERIENCE IN INTRODUCTORY ASTRONOMY USING ROBOTIC TELESCOPES

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by
Archana S Dobaria
San Francisco, California
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CERTIFICATION OF APPROVAL

I certify that I have read Impacts of a Course-based Undergraduate Research Experience in Introductory Astronomy Using Robotic Telescopes by Archana S Dobaria, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirement for the degree Master of Science in Physics: Conservation Astronomy at San Francisco State University.

Kimberly Coble, Ph.D.
Professor

, Assoc. Professor
Andisheh Mahdavi, Ph.D.
Associate Professor

Huizhong Xu, Ph.D.
Associate Professor

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Archana S Dobaria
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As part of a general education undergraduate astronomy course at a minority-serving university in the Midwestern US, students completed an observing project with the Global Telescope Network (GTN), where they participated in realistic practices used by professional astronomers, including proposal writing and peer review. This study investigates students' experiences and perceived impacts of participation in the project. The data analyzed includes an essay assignment [N = 59] administered over seven semesters and individual interviews [N = 8] collected over two semesters. Students were prompted to address what they liked, disliked, or would change about the project experience. These data were coded iteratively into nine categories. A Kruskal-Wallis (KW) test was used to determine that essay results from different semesters could be combined. We find that students expressed an overall strong positive affect, increased perception of self-efficacy, enjoyment of the experience of peer review, an appreciation for being able to use real scientific tools and to take on the role of astronomers, as well as a small number of dislikes such as real-world constraints on observing.

I certify that the Abstract is a correct representation of the content of this thesis

______________________________ 12/20/18

Chair, Thesis Committee Date

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I. INTRODUCTION

The purpose of this work is to describe the importance of the course-based undergraduate research experiences (CUREs) study model to entry-level astronomy (ASTRO 101) students and to analyze it's impacts on engaging students in authentic research experiences. CUREs involve scientific research projects: writing proposals, peer review, collecting and analyzing data, and sharing findings. The global telescope network (GTN) project introduces students to authentic scientific research experience in the field of astronomy. Authentic scientific research experiences have always been of importance for upper undergraduate students in all science fields. In astronomy, there are research programs provided by various institutes for students to gain research experience. However, such research opportunities are rare and often limited to students involved in the major. It becomes crucial for us to provide such authentic scientific research experiences to ASTRO 101 students since research is such an important aspect of science.

A. Framework

Engaging undergraduates in more research experiences has been regarded as necessary by the National Academies [1], the American Association for the Advancement of Science [2] and the President's Council of Advisors on Science, Technology, Engineering and Mathematics [3,4,5]. Many acknowledgments of the efficacy of research in undergraduate education have occurred in various scientific fields, leading to various projects that make research an integral part of the undergraduate curriculum [6,7,8]. Traditional ways of giving students innovative and practical experience are not sufficiently effective due to their limitations. For example, the one-on-one mentorship research model works well but is limited to a few students and is time-consuming. The traditional lab classroom setting does not provide the necessary authenticity, but instead teaches students to simply follow rules and guidelines. This type of classroom setting, or curriculum does not generate sufficient interest in learning science in students [8-11].

CUREs provide a solution to this situation by breaking the traditional structure of curricula and are proven successful to provide authentic research experience for all [12, 13]. CUREs offer the inclusion of all students and an opportunity to do authentic research in the entry-level classes through curriculum modifications [12-14]. CUREs have been an extensive part of biology and chemistry departments, so they played an essential role in shaping how to set a CUREs curriculum for various science subjects. The Course-Based Undergraduate Research Experience Network (CUREnet) was initiated in 2012 through NSF funding to provide a systematic explanation about CUREs. CUREnet is a network of people and programs that are creating course-based undergraduate research experience for undergraduate students. CUREs can be characterized by the following terms [12,14-17]:

- Scientific practice: Student or instructor driven designed to give more scientific research experience.
- Discovery of unknown questions: Student-driven process by which discoveries of unknown questions are answered by students.
- The broader impact: The broader relevance of the work done and how important it is to the community.
- Collaboration: Collaboration between students, teaching assistants, and instructors to provide better scientific research practice.
- Iteration: This is a process to iterate data and is built in the process.

CUREs is a mostly student-instructor-course driven curriculum model thus making it flexible for different courses by taking various forms. The CUREs can be a semester, several semesters or, a year-long study model. The similar flexibility applies to science educational research involving CUREs project as well.

B. Academic benefits of CUREs

CUREs advocate for teaching science through authentic research experiences for undergraduate students to provide opportunities to gain scientific skills needed to be a future scientist and citizen. Through the authentic research experience of CUREs, students have the opportunity to connect with the reality of the world of scientists. CUREs also provide an opportunity for students to connect the current knowledge learned in class to practical experience [18,20]. The way to learn science is through practical experiences, real discussions, and critical thinking. Students must have access to designed problem activities where they have an option to explore alternative solutions that inspire curiosity in dealing with the uncertainty or ambiguity of a problem [21]. According to Jerome Bruner's 'theory of instruction,' knowing is a process and meaning is constructed in the human sphere of culture by using a valuable tool called "narrative" [21,22]. We often try to interpret, understand, and make meaning through narration learned from our surroundings. CUREs generate a culture of education where students can learn and give meaning to science through practical and authentic experience.

A CUREs developed curriculum offers a wide range of academic benefits in learning science which can be divided into three main categories: cognitive growth, personal growth, professional growth [21]. Many research studies have demonstrated the benefits of the CURE model or authentic research experience in all three categories. The cognitive growth achieved through CUREs is inclusive of all educational fields therefore, educational research focuses more on this specific benefit. There are many studies in which participants demonstrates improved knowledge content [19,23-26], academic achievements, educational attainment [19,26], communication skills [23-25,26,27], analytical, intellectual, and critical thinking skills [24,27-33], writing skills [23,28], and ability to think or act like a scientist [18,24,25,27,31-33]. The development of cognitive skills contributes to the students' increased personal interest and professional confidence in science.

CUREs also help students' personal growth as leaners and future scientists by encouraging self-regulation, self- motivation, and inspiration to participate in working and learning science [24,25,31,36]. The characteristics like independent ability to think, learn and work [24,25,29,34-36] leads to self-identification with science [18,37]. Participants in CUREs gain a deeper understanding of the subject and are aware of its strengths and weaknesses, leading to professional growth. Professional growth categories include the ability to interact socially with fellow scientists [36], to work with each other and to learn how to collaborate and have a healthy discussion about their work [18,23-25], and enhances social interaction skills [38]. In some curricula, CUREs even offer opportunities to develop ties to the scientific communities [24,25], opportunities for more choices to pursue career in science [31,39].

Participants also showed increased confidence in doing science [23-25,40] leading to a positive change of attitude toward science. Students show increases in commitment toward the science subject and are motivated to pursue science in the future to stay connected on a longer term [18,29,27,36,41-44]. There is a significant improvement in career aspiration in all three areas: professional, research and attending graduate school [18,19]. The improved problem-solving skills and increased confidence in doing science are reflected in the increased self-efficiency of many students [18,23-26,31-33,40]. Minority-serving universities as well as first-generation college students showed improvement in analytical thinking skills [29,30]. Authentic research experience is an opportunity for students at an early stage of their career to understand and experience what it is like to be a scientist [18,19]. This experience helps students develop the necessary scientific skills to help find the right path for the future.

Authentic research through CUREs have been implemented widely in other science fields e.g. Biology, Chemistry, Environmental science, but still aches for acceptance in Physics and Astronomy fields. There are only a handful of projects done in observational astronomy where students get to use robotic telescopes at the university and high-school level [44-47]. Learning and knowing the sky through the telescope lens is the most commonly known aspect of astronomy, so it becomes more critical to have this experience for students. In the field of astronomy, the use of robotic telescopes for introductory students at a high school level as well as at an early undergraduate level shows significant benefit [45]. Introductory astronomy, commonly known as ASTRO 101, usually involves a cross-section of major areas of the college population [48-50]. The majority of the undergraduates enrolled in an introductory science classes are taking science class for the first and probably the last time at the college level [45,48,49].

Interestingly, a rough estimate of students taking general astronomy courses in the United States of America is ~10% [51,52]. Introductory courses provide a golden opportunity for both students and instructors where students have a chance to learn about the new form of science, and instructors get to influence and change student's minds. The fraction of college students shifting their interest or changing major during the initial years of a bachelor's program is about 30% [50]. Students' shifting interest toward astronomy hinges on classes like ASTRO 101. It becomes imperative for institutions to give authentic scientific experience to students who are commencing in the field of astronomy. In other words, students should experience what astronomers do to make the experience even more interesting, much closer to reality, and to develop scientific thinking skills. One of the pedagogical research studies in the field of astronomy indicates that it is possible to develop and deliver a rigorous, conceptually based astronomy course to non-physics major students [48, 53]. When we teach basic level astronomy, we affect the scientific literacy of all areas of education since the participants are a cross-section of the college population [50-52].

C. Curriculum

Our curriculum for the Global Telescope Network (GTN) project was inspired by the need to give students direct experience of the research process using scientific tools. The curriculum design is similar to that of McLin et al. [47], which outlined projects for K-12 and undergraduate students using robotic telescopes. McLin was part of our project team and helped instructors and students with operating the robotic telescopes via Skynet.

In creating the curriculum examined in this study, the creators first asked: "What is the end goal?" This question describes what the curriculum is trying to achieve. This question is vital since it leads to the follow-up question which is, "How can we engage more students in authentic scientific practice?" This question helps set up the curriculum which can engage more students in authentic scientific practices. A related question the curriculum tried to address was "How can we give students an experience similar to what astronomers really do?" Setting up a curriculum where we can incorporate the process of doing research and conducting research using scientific tools became easier with the help of these guiding questions. Coble designed the curriculum relevant to this study as part of a highly interactive studio-style introductory general education astronomy course with integrated lecture and lab components. The course met four hours per week, with approximately 15 students per semester. The Global Telescope Network GTN observing project was 10 – 20% of the course grade. The goal of the project was to make students familiar with using robotic telescopes and other authentic scientific practices of astronomers.

The initial step of the student project was to choose an object which would be observed using the robotic GTN telescopes [54]. Students were introduced to the astronomical tools Stellarium [55] and Skygazer [56] for choosing their objects. Stellarium (or Skygazer) is planetarium software that enables you to see an exact night sky picture for a preferred timeline, as shown in Figure 1. This program is straightforward to use. Since the majority of the participants are relatively new to these scientific tools, one of the challenges was to get them familiar with it in a short period of time. Students participated in an in-class Stellarium-activity for practice and were given more practice as homework. The goal of this assignment was to get students familiar with how to operate the software and gain necessary information. These assignments were designed to teach how to look for an object and its related information. The assignments included finding the name of an object, object type, and observing requirements like coordinates, etc. Students were required to write an abstract about the object of their choosing with all the necessary information for observation. Figure 2 is a sample observing sheet the students were required to fill out.

Figure 1: A screenshot of Stellarium, which was used for object selection.

GTN Proposal Cover Sheet

You will be using the Global Telescope Network to observe an object of your choice (planet, star, nebula, galaxy, etc.), visible from the GTN site in California (GORT) or in Chile (PROMPT) during April. The GORT telescope is located near Santa Rosa, CA and the PROMPT telescopes are located in Cerro Tololo, not too far from Santiago, Chile.

Basic Information

Title of Project: Wings of the Bird

Object Name(s): Alchiba (a-Crv)-HIP 59199

Type of Object: Star

Telescope (choose one): GORT / PROMPT

Observing Requirements

Coordinates (RA, Dec): 12h08m24.9s/-24o43'44.1"

Magnitude: 4.00
Your object must be between magnitude 3-12. Remember, lower magnitude is brighter.

Max Altitude and Time Constraints:
Your object should be at least 30 degrees above the horizon sometime during the darkest part of the night (approximately 9 pm - 4 am) in order to be observed.
What is a date and time when the object is high enough in the sky? What is its altitude (in degrees) at that time?
24 April 2013, 20:11:55 hrs Alt is 69o54'11"

What time will your object rise and set that day?
Rise at 15:10:51 hrs, Set at 4:20:57 on 25 April 2013

Figure 2: Sample GTN proposal cover sheet. Students were required to fill out the cover sheet and write an abstract on their project topic.

The next step was to write a proposal for observing the object with the GTN. The proposal body is three-four pages long with a cover sheet attached. The proposal was a shortened version of a National Science Foundation (NSF) style proposal and included background about the object, goals, objectives, and reasons for observing the objects. Just like NSF proposals, the last part of the proposal included dissemination of results and broader impacts of the objectives. Students were asked to submit a list of all the references in the proposal as well.

Following the observing proposal was written peer review, which was done anonymously by each student. Students were introduced to the Intellectual Merit and Broader Impacts criteria in NSF reviews and were guided by the instructor on how to review proposals and then assign an NSF rating of Excellent, Very good, Good, Fair, and Poor [57]. Each student was given two proposals to review. Proposals and reviews were anonymized using random code numbers.

Panel discussions were done following the written review process. The discussions were supervised by the instructor or teaching assistants in groups of students. During the panel discussion, students discussed which proposal should go first to last in terms of priority for observing. During the panel discussion session, each student was required to take notes on the discussion for one assigned proposal. Participants addressed related questions, discussed the answers and gave appropriate ranking to assigned proposals.

Robotic telescopes GORT [58] and PROMPT [59], shown in Figure 3, were used to observe the objects. Both telescopes were remotely accessed through *Skynet* [58, 589], to do the observations. The objects were queued up in Skynet (Figure 4) for the observation by students with the help of instructor.

Figure 3: Robotic telescopes. [Left] Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT) is an array of six 0.41-meter telescopes located in CTIO in Chile. [Right] The Gamma-ray Optical Robotic Telescope (GORT) is a 14" diameter telescope located near Santa Rosa, California.

Figure 4: Screenshots from the Skynet interface. [Left] Observation list. [Right] Adding a new observation.

Presenting their experiment along with gathered data and results was one of the important sessions of the project. The process of presentations followed the same format as presentations at meetings of the American Astronomy Society (AAS). Namely, each presentation was five minutes long plus two minutes for a question-answer session. The goal behind this was to introduce students to a professional presenting style environment.

The final step of the curriculum was to write a one-page long reflection essay describing students' experiences with the GTN project. The reflection essay is the most important part if the curriculum for our research study because it is the main medium by which we collected qualitative data. The prompt for the essay included students' overall likes, dislikes, suggestions for changes, reasons, etc. The instruction for the reflection essay is as follows:

> *"This should be a 1-page summary of what you liked, what you disliked, and what you would change about the project experience and why."*

D. Present Study

Our goal in this study is to determine and document the impact of authentic scientific research experience on ASTR 101 students in a studio-style class setting. The author's role was to analyze the documented data through an iterative thematic coding process described below. Research questions asked during the process of creating categories were a helpful tool in shaping the analysis. One of the questions was, "What did students take away from the GTN project regarding content and affect?" This gave an insight into how helpful this project is compared to a traditional lab-based classroom. Another question asked was, "Did students describe their experience as including authentic scientific practices and tools?" This question explored the purpose of this curriculum which was to give students a more realistic scientific experience.

II. METHODS

A. Methodological Framework

There are two broad research methods with which education research can gather and analyze data about the subject: quantitative and qualitative [60-62]. A qualitative approach is used to gain a deeper understanding of how students think, interact and behave. It provides insights into underlying reasons, problems, motivations, opinions, etc [60, 63]. This research method is most useful to uncover trends, create a hypothesis, and goes deeper into the problem at hand. Qualitative methods involve describing, exploring, seeking to understand a particular phenomenon or lived experience. This method typically uses small samples providing a deeper understanding of a specific situation. The research design is not decided in advance in all cases; it may emerge during the study or analysis phase. In other words, this method is researcher subjective [60-63]. The GTN project was designed to target a a small group of participants at a minority-serving university. The goal of the research design was to gain insight into participants' lived experience; thus qualitative methods were used for this study.

The design of this qualitative educational research is inspired by theories described by Levy et al. [64], which guide our analysis throughout. In general, any research design includes initial philosophical phenomena which can be divided into four main components: epistemology, theoretical perspective, methodology, and methods [64]. A choice of a philosophical paradigm depends on what the research study is trying to accomplish, and such paradigm is defined by its ontology, epistemology and research methodology. A paradigm is "the set of common beliefs and agreements shared between scientists about how problems should be understood and addressed" [65]. The paradigms used for four steps of research as mentioned in Levy et al. [64] are constructivism, interpretivism, grounded theory, and quantitative data collection.

Jean Piaget's epistemic belief in constructivism immerses itself in the nature of knowledge in order to discover the underlying meaning of events and activities [66-68]. The constructivist approach enables participants to build new knowledge on existing knowledge and to develop new ideas. This approach is experience-based and does not allow the environment to interfere with the learning and processing of new information, making it more learner-oriented or driven. The constructive approach allows the researcher to explore the view and understanding of the various participants in the context of the subject and recognizes that each participant has a different understanding of the same situation [63]. The qualitative method in constructivism provides insights into underlying reasons, problems, motivation, opinions, etc. [61,64,66,67]. The GTN research project uses Piaget's beliefs of learning through the construction of meaning where our team is trying to discover the truth about student's experience in a different educational setting through interaction [67-69].

The interpretivism paradigm emphasizes the path of the information, learning events and knowledge to encapsulate activities [67,68,70]. Interpretivism is a subjective approach and parts away from the traditional model of learning and is more learner-centered and reproduces a series of facts, belief, behavioral changes, attitude, etc. [65,69-71]. The interpretivism perspective has played an essential part in influencing learning by designing activities which focuses on 'cultural meaning' phenomenon [21]. The term 'cultural meaning' hints at the fact that meaning is created cognitively based on the culture or environment [22]. Using interpretivism, Bruner has put emphases on learning motivation by interest in which students are apt in learning a meaning if they are interested [22,65,71]. This perspective gives a perfect structure to know, learn, and understand through practical experience. One of Bruner's famous quotes "Learning is a process, not a product" is the best representation of the interpretivism perspective since this theory stresses going beyond the information given and what you learn [22,65]. Our curriculum goal was to introduce students to more practical experiences in the field of observational astronomy as well as peek into astronomer life. Introducing students to a robotic telescope to take the observation is a rare and unique experience at an undergraduate level to increase interest and influence learning.

A qualitative approach has five types of research methods design: ethnographic research, case study, phenomenological research, grounded theory, narrative research [60,63,72]. Among these methods, the GTN project adopted a grounded theory approach due to it is evolving nature throughout various semesters. As the project progressed, the curriculum guidelines were adjusted according to the responses of the students after each semester. Grounded theory is one of the oldest research methodologies that enable us to develop a theory that explains the phenomenon based on the participants' experience [63,73]. The dual identity feature as a method and product of investigation provides a research tool for qualitative analysis to detect emerging data patterns [66,70,73]. Grounded theory is an interplay of experience, induction, and deduction that generates theories and hypotheses from data and has a method of collecting and analyzing data through study design during the development of the model [63,66,72-75]. Employing a systematic category identification process that is based on events, processes, occurrences encourages researchers to carry out a continuous review process that leads to the formulation of the research design. Since there were no initial proposals for the research project, grounded theory is a suitable method to use [61,63].

The coding process in grounded theory is critical and varies depending on the type of data as well as what is it that you are looking for. The first step in the process of research coding is an open coding method, which is a line-by-line data analysis. The open coding process provides detailed observation, definition, and actions to emphasize implied concerns and explicit statements [74,75]. Open coding helped to create and define categories from the collection of written narrative data. Thereafter, an axial coding method was used to combine original codes into major categories and to define subcategories and their relationships [63,64,74,75]. These categories and themes were turned in data frequency counts to create bar plots to get a better understanding and are shown in Section III. The only precaution required here is that you must be careful of any personal biases and that you can remedy them using statistical analysis. A statistical analysis of our data through validity testing and reliability testing is also detailed in Section III.

B. Participants and setting

The ASTRO 101 class studied in this work is an introductory undergraduate course for students of both science and non-science backgrounds. This course is intended to introduce the students to basic astronomical concepts. The class was set up at Chicago State University (CSU), a minority-serving university in the Midwest. There was no collection of individual demographics in order to maintain the anonymity of the population.

The ethnically diverse CSU undergraduate student body is comprised of four main groups: African American (75.2%), Hispanic/Latino (7.7%), white (2.7%) and, Asian/Pacific Islander (0.6%) [76]. The unknown ethnicity is about 12% of the total number of undergraduate students. Chicago State University is predominantly female, where almost 70% are female and 30% are male students. [77]

C. Data collection

Students were prompted to write a one-page essay at the end of their project with a fundamental guiding question. The instruction for the essay was "This should be a 1-page summary of what you liked, what you disliked, and what you would change about the project experience and why." In their reflection essays, students were asked to express their thoughts and an honest assessment of the GTN project. For the analysis, the essays were an anonymous code number in order to minimize bias. The other method of data collection was semi-structured one-on-one audio interviews with the instructor and research assistants. The interview questions were prompted based on the students' response to the previous question, and the responses were recorded using pseudonyms (code names) and later transcribed into written manuscripts.

Examples of interview questions asked by instructor during one-on-one interview sessions included:

- What did you think of the GTN project?
- What did you like about the project?
- Have you ever done any astronomy or scientific research before this class?

- What you thought about the project process so far? How did you like doing the review panel?
- Does this project change your impression about what astronomers do and if so, how?
- Did this project help your understanding of topics that you learned in class?

The data was collected through seven consecutive semesters from Fall 2008 to Spring 2014 as shown in Table 1. The classroom size for this undergraduate course was approximately 15 to 20 students resulting in total 59 reflection essays. The interviews were done during two semesters with 8 students total.

Table 1. Data collected for each semester.

Semester	Essay	Interviews
Spring 2014	9	3
Spring 2013	12	
Fall 2012	7	
Fall 2010	13	5
Spring 2010	10	
Spring 2009	6	
Fall 2008	2	

III. RESULTS

A. Frequencies of categories and themes

The coding process using grounded theory lead to nine main categories. Figure 5 shows all nine categories by frequency, where *positive affect* has the highest number of frequency counts. Each category is composed of several themes.

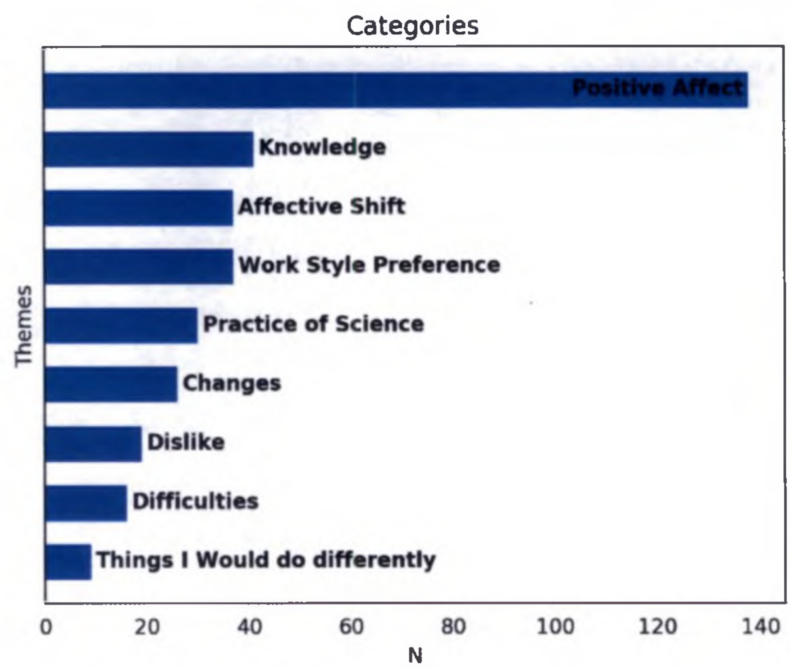

Figure 5. Categories by frequency counts.

Positive affect is one of the most significant popular categories (N = 138 out of 371 data points) amongst all the categories defined. The *positive affect* category includes all the aspects of the curriculum viewed in a positive light by students. Favorite themes in this category were *overall positive* and *peer review*. Table 2 shows the characterization of each theme via example quotes and Figure 6 shows frequency counts by all the themes for this category.

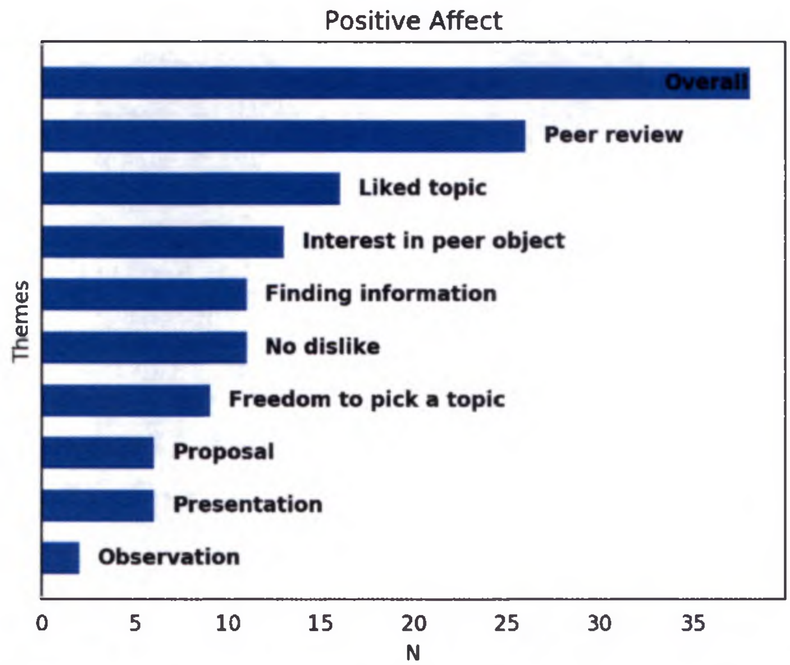

Figure 6. Frequency counts by theme for the category of *positive affect*. Students described what was it that they liked about the project overall as well as specific aspects.

The most popular theme, *overall,* includes quotes which describe positive experience about the GTN project. The theme *peer review* characterizes participants' indicated interest in the peer review process. Other present themes were: *liked the topic, interest in peer's object, finding information, no dislikes* and *freedom to pick a topic*. The themes *liked topic* and *freedom to pick a topic* included quotes about the pleasing experience about the chosen topic by students and identifies positive experience where participants liked the freedom to choose their own object. The theme *no dislike* identifies experience where students simply had no dislike about GTN project. Themes *proposal* and *presentation* had almost the equal number of frequency counts. The theme *proposal* illustrates the participants' liking to write the proposal and the involved process towards it.

Table 2: Examples of each theme in the category of *positive affect*.

Theme	Example
Overall positive	The project was the highlight of the class.
Peer review	Peer review was my favorite part of the project
Liked the topic	I was truly pleased with my selection for the GTN Project
Interest in peer's presentation/object	I really enjoyed listening to other people present their projects. That was the best moments of the class.
Finding information	Doing research allowed me to learn more about an object in our universe.
No dislike	There was nothing I didn't dislike about the Proposal
Freedom to pick the topic	What I liked most about the project was that we had the freedom to pick our own object to research.
Proposal	I liked writing up the proposals.
Presentation	The presentations were great.
Observation	What I enjoyed about the project was doing the observation and the background of my object.

One of the categories derived through data analysis is *knowledge* with N = 41 out of 371 data points dedicated to it. This category belongs to the popular category group (category with frequency count N>35) and is second most popular after the category of *positive affect*. This category includes three roughly equally popular themes, as seen in Figure 7. The three themes are: *learned about the object*, *overall informative* and, *application of knowledge*. *Learned about the object* includes participants' excitements of learning more information about their object as well as their peers'. The *overall informative* theme includes the helpfulness of the GTN project in learning and gaining general information. The theme *application of knowledge* includes students' self-described ability to apply the obtained knowledge in the future or to apply knowledge learned in class to their project. The example quotes for each theme are listed in Table 3.

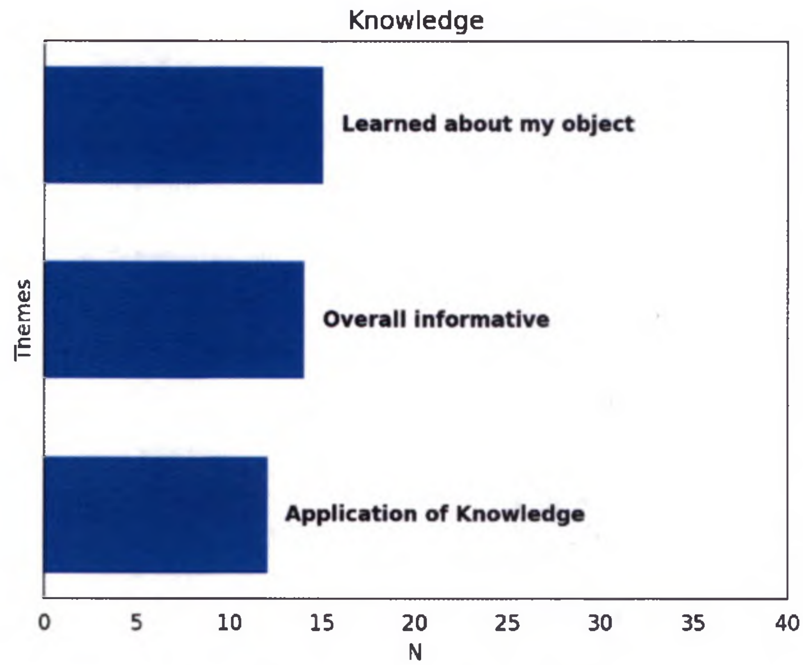

Figure 7: Frequency counts by theme for the category of *knowledge*, describing knowledge gained by students by participating in the project.

Table 3. Examples of each theme in the category of *knowledge*.

Theme	Example
Learned about the object	I found out a lot of information in regard to my Spiral galaxy… I did learn that the M81 has some similarities to the Milky Way galaxy.
Overall informative	I found this project very informative.
Application of knowledge	After doing research and having this astronomy class I am more comfortable listening to astronomers speak about the universe because I now have a better vocabulary and understanding of the terms.

Figure 8 shows the frequency of themes within the category of *affective shift* of participants. Themes include: *increased self-efficacy*, continued practice, *self-enlightenment*, *changed preconception, and increased interest*. The *theme increased Self-*

efficacy incorporates participant's personal assessment of increased belief in the ability to achieve various goals. *Continued practice* includes willingness or volunteering to continue any aspect of this project, e.g., observation. The theme of Self-Enlightenment describes acknowledgment of participants' shortcomings throughout the project and willingness to fix it on their own. Theme *increased in interest* characterizes gaining more interest in the project along the process. Table 4 shows examples of quotes for each theme.

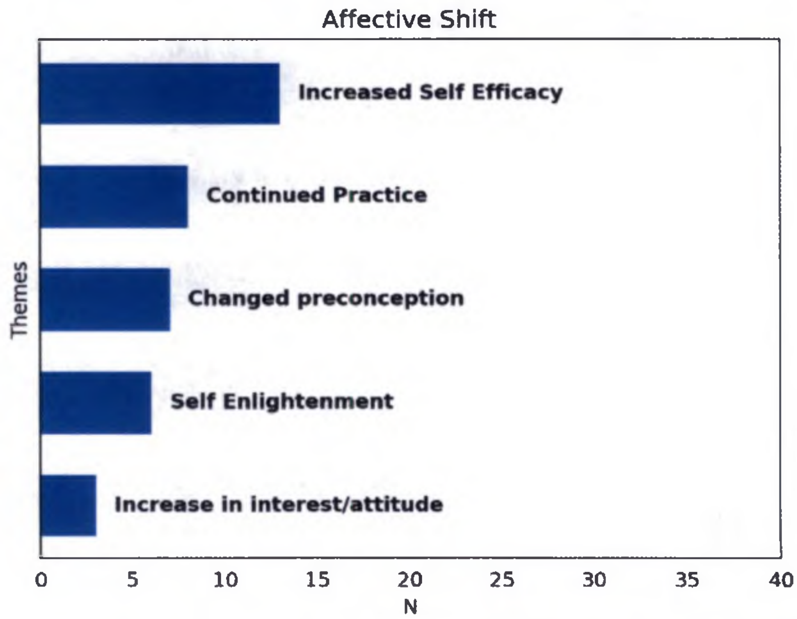

Figure 8. Frequency counts by theme for the category of *affective shift*. All the themes in this category are positive and shows students personal growth from this project.

Table 4: Examples of each theme in the category of *affective shift*.

Theme	Example
Increased Self-Efficacy	This project challenge me to seek new sources for information, it made me think outside the box and see the true value of the course.
Continued Practice	For sure this summer I will have the curiosity to find some more object and spend some time on the Stellarium program.
Changed Preconception	The project was not as bad as I thought it would be.

Self-Enlightenment	It helped me to learn some things I didn't know a corrected me on thing I thought I knew.
Increase in interest	The more information I got on my object the more interested I became with doing this project.

The *work preference* category is one of the most popular (N=45 out of the total frequency count of 371) among all categories. This category dealt with the amount of work, the time required to complete the project and the experience of finding information about a chosen object. Figure 9 demonstrates work related themes derived from the reflection essays. Examples of these characteristics for each theme are shown in Table 5.

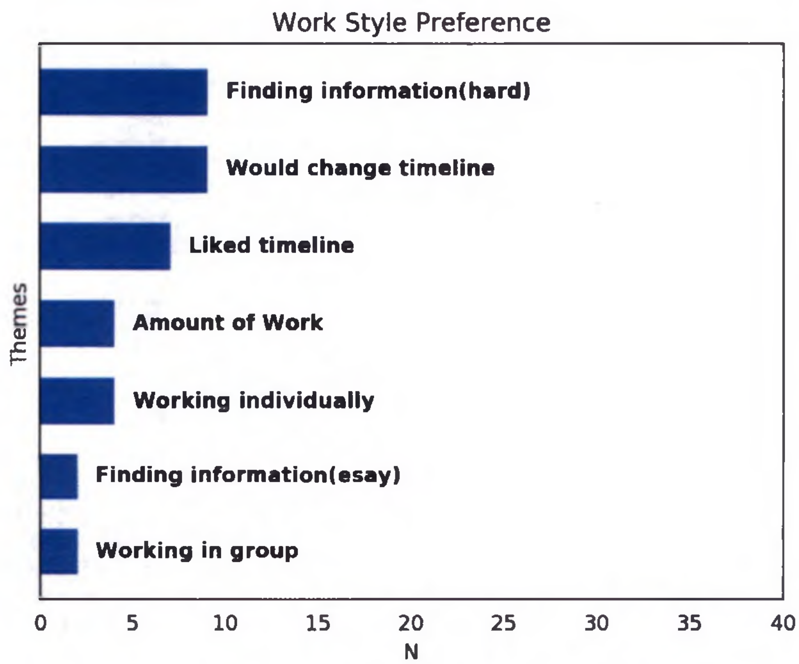

Figure 9. Frequency counts by theme for the category of *work style preference*. Describes student's works style preference in various themes.

Table 5: Examples of each theme in the category of *work style preference*.

Theme	Example
Finding information (hard)	looking up well researching my particular star was a little difficult because it wasn't that much information that I could find.
Change timeline	I would change the timeline on the project, maybe by just an extra class day per part.
Liked timeline	Time-time frame between assignment was very reasonable and gave me enough time to research my project and have it ready to turn it by the due date.
Amount of work/just right	The amount of work put in to this project was reasonable.
Working individually	I very much enjoyed this project; especially the part where we get to work individually, since working in groups is not my thing.
Finding information (easy)	The researching the information was interesting as well.
Working in group	Make it a group project as scientists do their research in groups and I think it would add more to the learning process for the students.

One of most crucial categories derived through data analysis is *practice of science* with 40 out of 371 data points dedicated to it making it part of the popular category group (category with frequency count N>35). The project hinges upon this category as this will partially determine the success of the project. The two themes in this category Experience of using scientific tools and Real scientist like experience were equally dominating as seen in Figure 10. Experience of using scientific tools captured the experience of using software like Skynet, Stellarium, Skygazer, and use of robotic telescopes for the first time. The theme Real Scientist like Experience included characterization such as panel discussion, review process, NSF style rating system, observation, and presentation. The experience includes learning about what scientists do, getting an experience like real life astronomer while doing observation, panel discussions. Table 6 demonstrates example quotes for each theme.

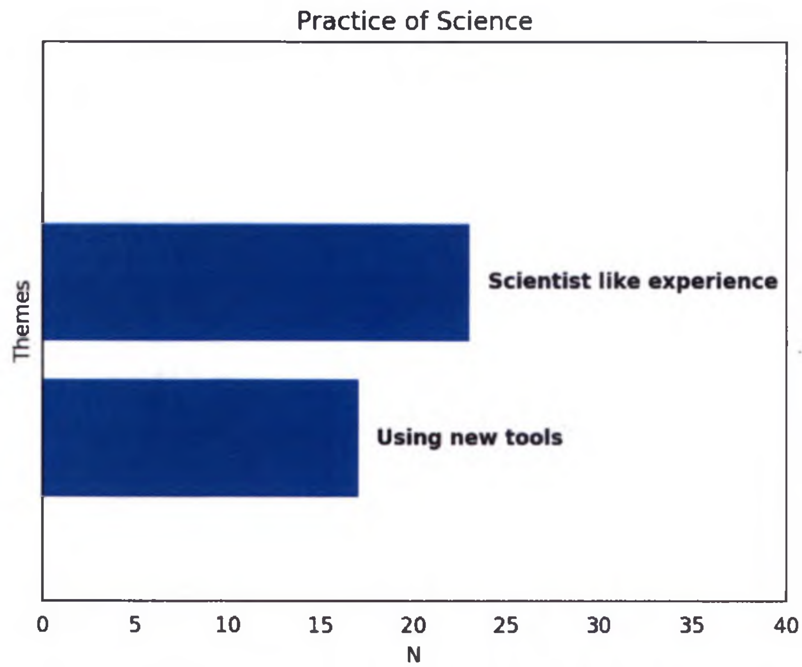

Figure 10: Frequency counts by theme for *practice of science* category. Describes the general experience in science as a future scientist. The data shows students enjoyed taking a peek in the "real world" scientist life.

Table 6: Examples of each theme in the category of *practice of science*.

Theme	Example
Real scientist like experience	We got a chance to go through what real scientist in this field actually do on a daily basis.
Experience of using scientific tools	The most exciting part was getting the objects picture taken by the GORT Telescope.

The categories *changes, dislikes, difficulties, and, things I would do differently* are the least present categories. The category *changes* include themes like overall, observation, peer review, list of topic, presentation, and proposal (Figure 11). As shown in Figure 12 the most present themes in *dislike* category were a real-world problem and, peer review. Table 8 presents examples of quotes in this category. The category *difficulties* had three themes as shown in Figure 13. The themes are guidelines, choosing an object and, interpreting data and the examples are shown in Table 9. Last category *things I would do differently* has characteristic like writing a proposal differently, different experimental analysis with the data, gathering more information about the object and examples are shown in Table 10. The frequency counts present in this category are demonstrated in Figure 14 in the bar chart.

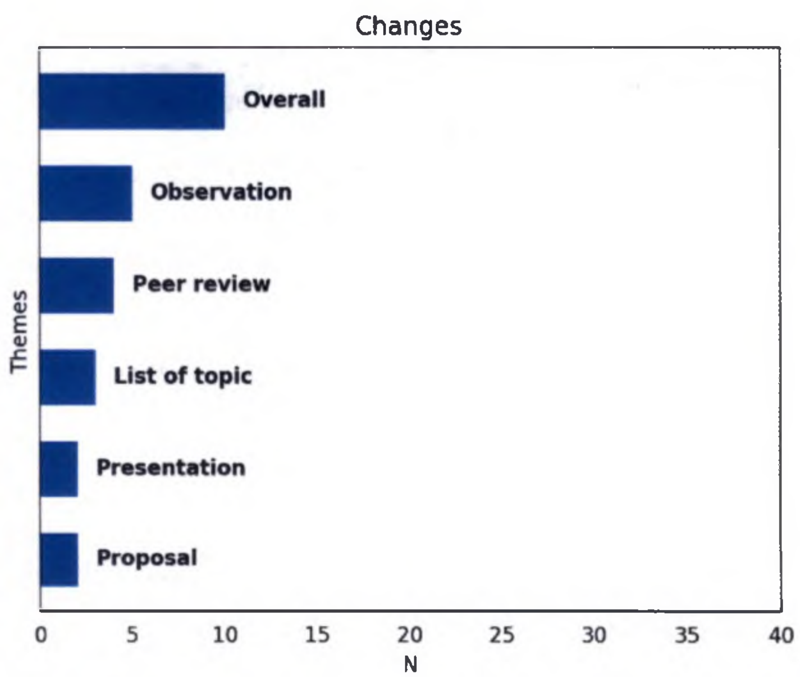

Figure 11: Frequency counts by themes for the category of *changes*. Describes the changes recommended by students in their essays.

Table 7: Examples of each theme in the category of *changes*.

Theme	Example
Overall	Just wish we could have gone further in depth with the assignment.
Observation	Have each student find their own pictures through the GTN telescope if possible.
Peer review	I would have two recorders instead of everyone recording critical information for the improvement of the proposal.
Need list of objects	I like there should have been a list of maybe forty objects that met the requirements.
Presentation	I felt the presentation should have been carried out in two days instead of the one that was given.
Proposal	If I had to change something about this project, it would be the word proposal only.

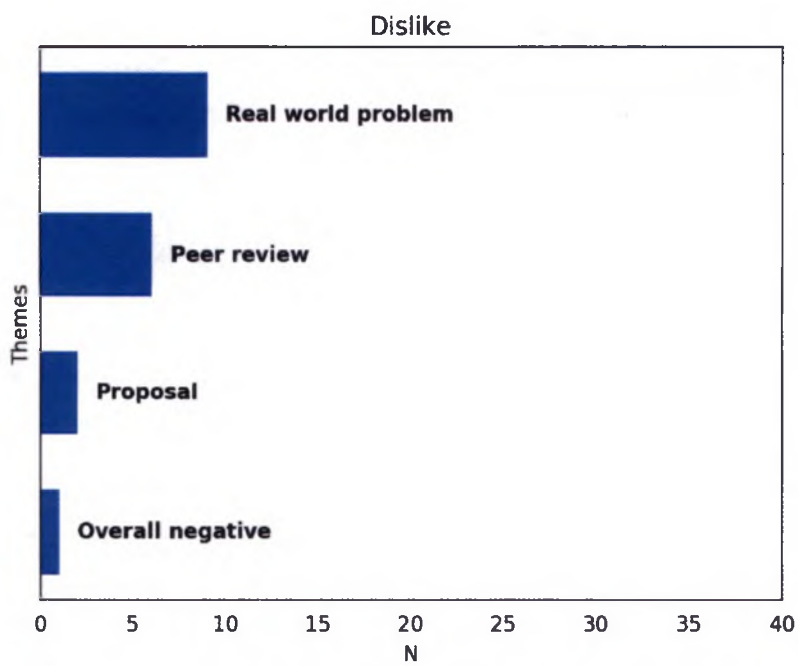

Figure 12: Frequency count by theme for the category of *dislike*. Shows dislikes of any project activity.

Table 8: Examples of each theme in the category of *dislike*.

Theme	Example
Real world problem	I couldn't see my object at the time of observation, but that had nothing to do with the project itself.
Peer review	When we had to do those reviews that was the confusing part because everyone went in a different direction in how they interpret the directions.
Proposal	Putting together my proposal was difficult at times because my inclination was to base my project around the deliverable data gathered and analysis.
Overall Negative	The project could be done without using Skygazer program. The only issue I had with that was, it was sometimes hard to access it because I didn't have my computer.

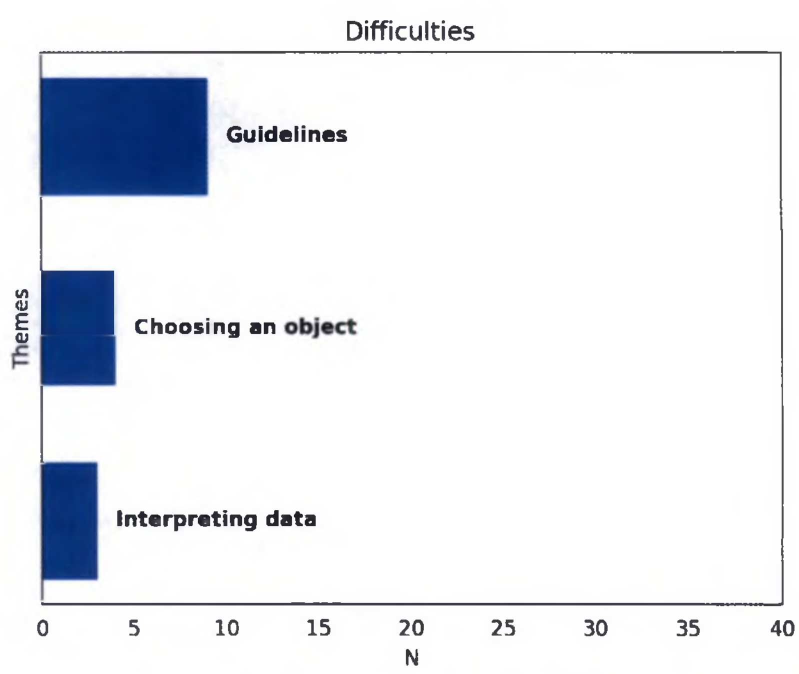

Figure 13: Frequency counts by theme for a category of difficulties. Describes difficulties encountered by students attaining various tasks of the project.

Table 9: Examples of each theme in the category of *difficulties*.

Theme	Example
Choosing an object	Difficult-choosing an object to observe was somewhat difficult
Guidelines	Explanation- I felt like we should've had a clear understanding of what exactly we had to do with this project
Interpreting data	I had a difficult time finding out exactly what information I could get from a photograph.

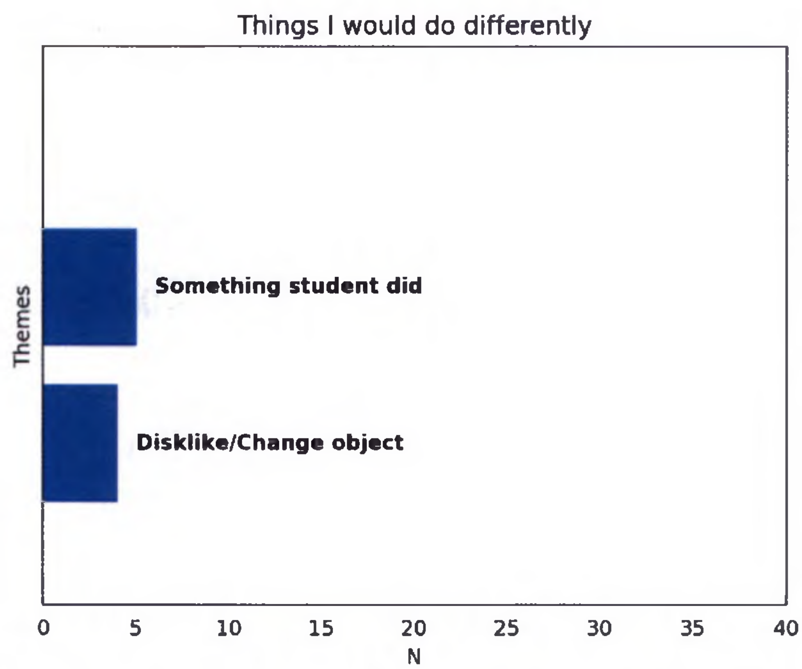

Figure 14: Frequency counts by theme for a category of *things I would do differently*. Shows anything which student would prefer to differently base on the experience of this project.

Table 10: Examples of each theme in the category of *things I would do differently*.

Theme	Example
Mistake student made	The only think I would change in conducting this project would be to compare and contrast other cluster in our galaxy and see whether or not the luminosity is more or less significant in another stars/cluster.
Dislike or change object	The only thing that I would possibly change is the topic that I choose.

The second method for data collection was one-on-one audio interview. Data collected through audio recording were manually transcribed in texts. Interviews were an attempt at gathering qualitative data with more than one way. This method helps students gain more confidence in a one-on-one conversation and potentially allows us to probe their thinking in more detail. However, as discussed in Section IV (limitations), we were not able to gather a large amount of data. Most of the quotes from the students corresponded to their written accounts. Table 11 shows one of the examples of this interview-essay comparison.

Table 11: Example of one student's quote comparison for essay and interview.

Student name: *Richard*	Essay	Interview
Interest in peer's object	I liked the presentations from the class, there were some good presentations.	It was interesting to hear the opinions and reasoning of fellow student astronomers.
Peer review	I liked the review panel.	I also liked the Panel review portion of the project. It was interesting to hear the opinions and reasoning of fellow student astronomers.

Experience like a real scientist	It was cool being able to do observations of a real object. I liked the fact that we were able to observe a real astronomical object.	The idea of finding a real cosmological object with a real telescope is something I think most people would want to try if given the opportunity
Observation	It was cool being able to do observations of a real object.	No quote.

B. Statistical Analysis

Statistical tests for qualitative data depends on three main variables data, sample and purpose [78,79]. For example, Kruskal Wallis (KW) test is carried out for nominal or categorical data to test its validity [80,81]. The purpose and type of data determines the type of statistical test that needs to be done. For the GTN project, two different raters analyzed and categorized the same data: 'reading essay.' The reliability test is performed on these analyzed data samples to determine the consistency of the gathers data. Once the data passes the reliability test the qualitative data were converted into nominal data to perform a validity test.

Reliability

Qualitative data analysis is sensitive because it depends on the interpretation of the researcher and the biases of any theory or research methods. Consequently, the reliability test must be done in order to establish the validity of the research. Inter-Rater Reliability (IRR) is a statistical measure which determines the similarity of collected data by more than one different rater. The Cohen's kappa (k) calculation one of the several ways to statistically measuring IRR. Cohen's kappa (k) measures the inter-rater reliability for categorical scales measured by two or more raters. The characterization of this test is that raters ' response is measured on a nominal scale final category are fixed excluding from each other. The response variable from different raters has the same number of categories that creates symmetric crosstabulation. One of the critical assumptions in the IRR test is that the response data observe the same phenomenon in pairs and that both raters evaluate the same observation [82].

The equation to calculate reliability is as follows [82,83]:

$$Reliability = \frac{\#\ of\ agreement}{\#\ of\ agreement + \#\ of\ disagreement}$$

Cohen's kappa takes chance agreement due to raters guessing into consideration, so the general reliability equation becomes:

$$k = 1 - \frac{1 - p_0}{1 - p_e}$$

where

p_0 = The relative observed agreement among raters.

p_e = The hypothetical probability of chance agreement

and the k value varies from 0 to 1 where 0.1 to 0.20 means slight agreement, between 0.21-0.40 means fair agreement, 0.41-0.60 moderate agreement, 0.61-0.80 substantial agreement, and 0.81-1.0 almost perfect agreement. Cohen's *k* was run to determine if there was an agreement between the two raters' analysis of the student's expressive essay. There was a moderate agreement between the two diagnoses k = 0.45740565. After having a thorough inter-rater group discussion, the nominal data table was finalized after reaching 100% IRR agreement.

Validity

The term validity has been defined and described by various authors over the years. The degree to which a test measures what it claims to measure is one of the most used and acceptable definitions of validity [64,78,81]. Kruskal–Wallis (KW) test determines whether we could aggregate results from different semesters and is used for three or more sample populations [81,84]. Once we define the null hypotheses, the p-value can be calculated to determine the validity of the defined hypotheses.

The following hypotheses were tested for those responses requiring a KW-test:

H_0: There is no difference between treatments

H_1: There is a difference between treatments

The p-value or H-test determines if the null hypothesis could be rejected or not. Our threshold alpha was set to standard 0.05 so if the critical value for chi-squared is <H than we can accept the null hypothesis. This is one way to determine if the categories can be combined or not. Another test could be to calculate the p-value for that if $p > 0.05$ our results can be combined. For the ASTRO 101 class under consideration, the KW test was done for existing nine categories for all seven semesters. The H-value and p-value was calculated using the following equation [80,81]:

$$H = \left(\frac{12}{n(n+1)} \sum_{j=1}^{k} \frac{T_j^2}{n_j}\right) - 3(n+1),$$

where

n = sum of sample sizes for all samples, (I = 1, 2,....,k)

k = number of samples,

T_j = sum of rank in the j^{th} sample,

n_j = size of the j^{th} sample.

This calculation must have at least five sample sizes (n_j) for the approximation to valid, we treated nine categories as a sample size. Degrees of freedom is calculated using the following equation:

$$df = k - 1,$$

where *k* is the number of groups or categories.

In Table 12 each semester is a group of various categories giving us seven total groups. After ranking each data point the mean rank of each group is calculated. The mean ranks of each group is listed below:

Mean ranks for group 1 = 36.83

Mean ranks for group 2 = 41.11

Mean ranks for group 3 = 32.16

Mean ranks for group 4 = 38.61

Mean ranks for group 5 = 35.10

Mean ranks for group 6 = 28.33

Mean ranks for group 7 = 15.06

H statistic value calculated form the mean ranks value is 12.056090. The critical value in the chi-square table for the given alpha value and 6 degree of freedom is 12.5916. This indicates that we can accept the null hypothesis. The p-value calculated for the H statistic value is 0.060729 that is greater than the alpha value (0.05); hence it is valid to merge all categories between semester. The scattered plot for the group ranks to calculate the *H-value* is sown in Figure 15. The bar graph shown in Figure 16 for each category captures the difference in proportion between the categories for each semester. The difference in frequency counts is consistent with the number of students for the related semester.

Table 12: Frequency counts of categories as a group for each semester.

Categories	Spring 2014	Spring 2013	Fall 2012	Fall 2010	Spring 2010	Spring 2009	Fall 2008
Positive Affect	25	21	15	21	24	23	9
Knowledge gained	5	8	6	10	7	3	2
Affective shifts	8	10	5	5	6	3	0
Work style preference	11	10	2	11	6	3	2
Practice of science	5	9	5	9	5	4	3
Changes	3	7	3	3	3	7	0
Difficulties	4	2	3	0	5	1	1
Dislikes	1	2	4	5	5	2	0
Things I would do differently	2	2	1	2	1	1	0

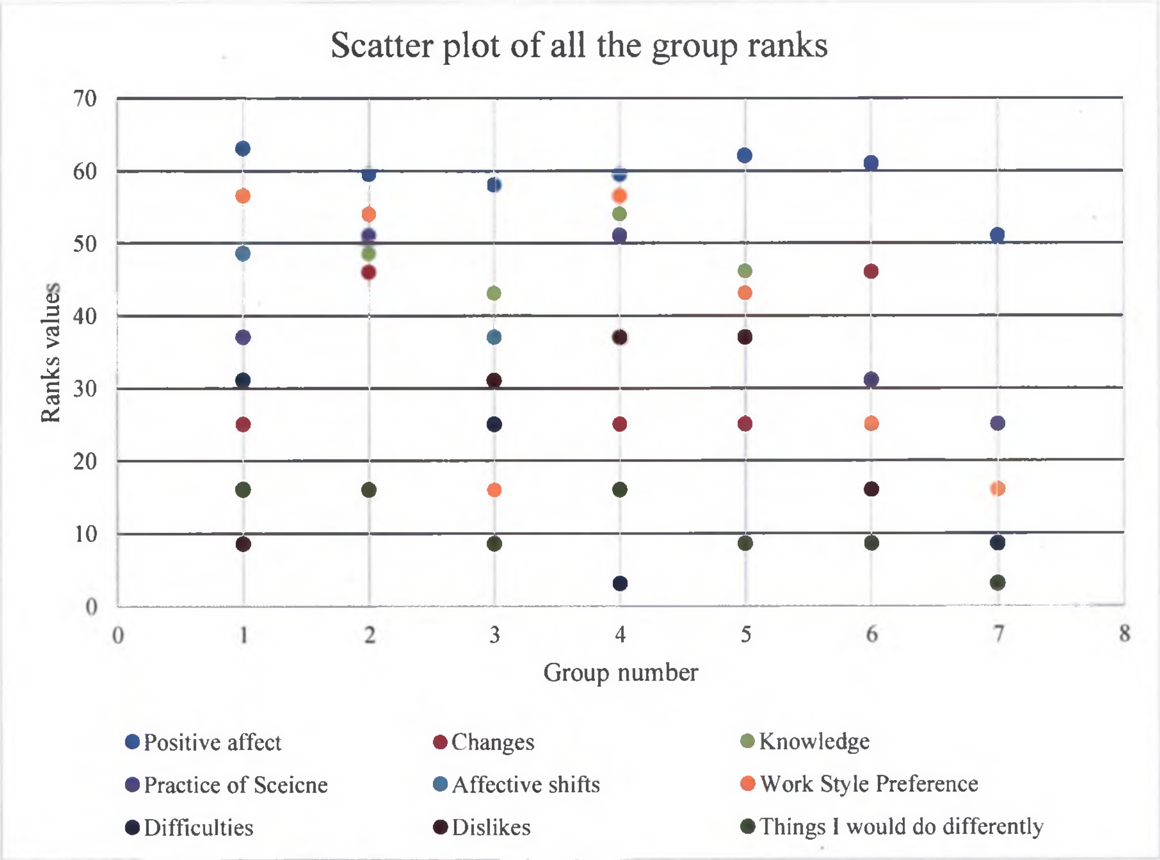

Figure 15: Scatter plot of all the group ranks for Kruskal-wallis test. Here each semester's nine category is given a rank value and are plotted vertically. The X-axis represents semesters as a group.

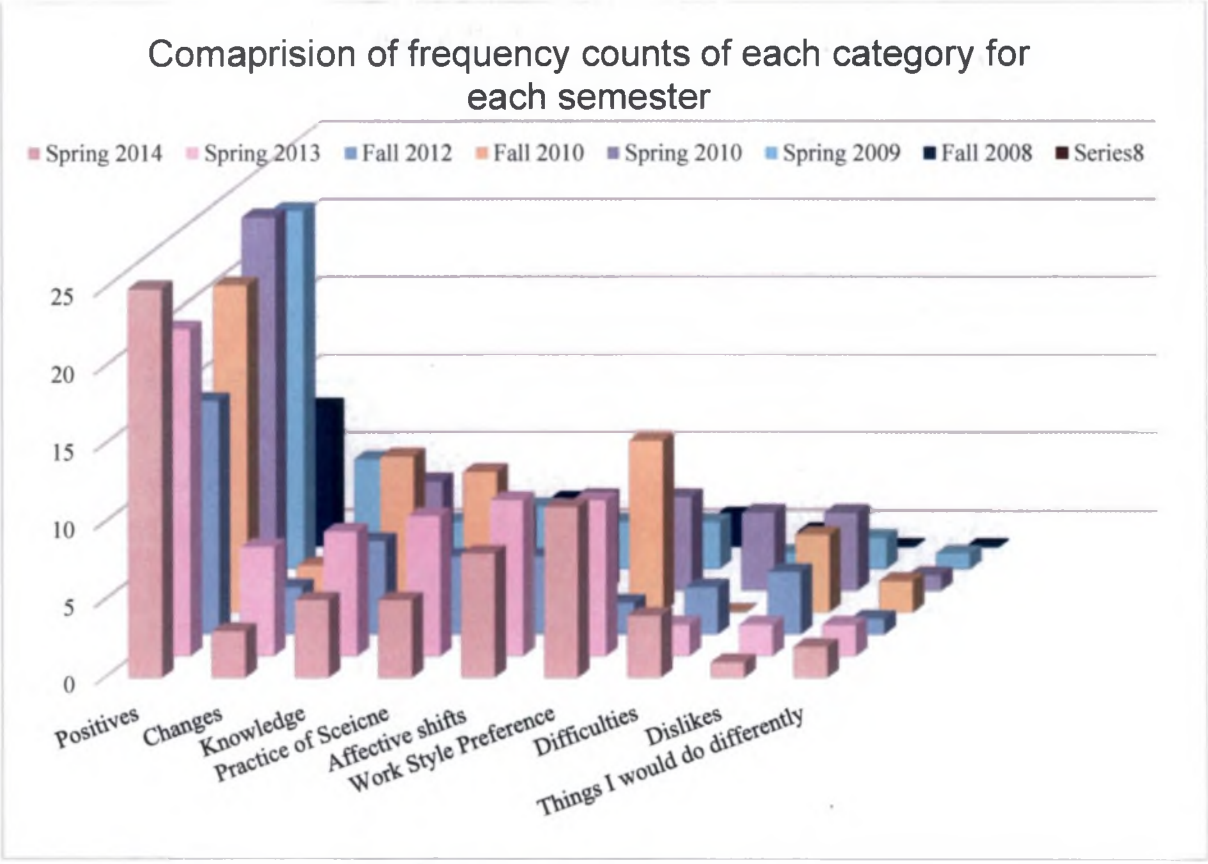

Figure 16: Comparison plot for categories of each semester

IV. DISCUSSION AND CONCLUSIONS

A. Benefits of the GTN project

Positive affect deriving from a real scientist-like experience:

The goal of giving real scientist-like experience was successfully achieved according to the student's quotes in Table 1, Table 6, Figure 10. The highlight of the project was peer review, panel discussion, and observation. Student's showed great interest in participating in peer-review, panel discussion and learned about NSF style rating system. This was the highlight of the project as this experience reflected in all the positively influenced categories. Student's showed increased in self-efficacy because they felt that they could also conduct research. This category also influences a desire to continue exploring the subject. Students showed a great deal of confidence boost in doing science which made it even fun to study for them.

Observation experience:

One of the benefits of the GTN project is that it gives students a peek into an astrophysicist's life. One of the most critical tasks is to observe which comes with its difficulties. Being familiar with all the difficulties would help students understand the astronomy life better. Doing observation is not always a smooth road, as the weather would not permit, or the object that participant wants to observe is not up in the sky at the desired time, or, the object is not in the plane of sight from the observation place. Students got to experience all this through the GTN project.

Students also enjoy using new scientific tools to observe through a telescope. This is a rare opportunity for students in ASTR 101 class as a result, it peeks their interest in pursuing the subject for the right reason. This makes students feel more relevant to the subject as well as astronomers' work and it links back to all the benefits of real scientist like experience category. Conducting real observations also gives them an opportunity to see what astronomical objects look like through telescope which helps them clear a few misconceptions about astronomy.

Affective shifts:

The results show a significant increase in the self-efficiency of the students throughout the GTN project. The *affective shift* category demonstrated the excitement of achieving a goal on their own by student's quotes like: "This project challenges me to seek new sources for information, it made me think outside the box and see the true value of the course." Participants were able to reflect back on their work through the peer-review process and group discussion and gain a great deal of self-enlightenment about their own mistakes. The reflection essays also showed student's belief towards completing tasks from the curriculum. The GTN project also enhances student's confidence of presenting in public and skills to have a detailed conversation about their topic. Students' quotes like: about becoming a better writer through proposal writing links back to the academic benefits of CUREs model. One of the examples of such a quote is: "This was a very good writing experience for me. This is what I needed to help me become a better writer". We can say that the GTN project enhances student's confidence in doing science and improves learning and growing by reflecting back on their work.

Continued practice:

Astronomy 101 students often forget about the subject once the semester is over and move on to their own primary subject. However, The GTN project showed participant's interest in continuing the practices beyond the classroom curriculum. This project seeks student's interest in astronomy by increasing their curiosity. The project is capable of student's attitude change towards astronomy as well as significant change. This shift of interest towards the subject is a result of student's experience of a real scientist like experience involving observations, proposal writing, and peer review process.

Clearing misconceptions:

The entire process of the project breaks the misconceptions students hold about the research process. Most of the time physics and astronomy students at an entry level have a notion that the subject is all theoretical, math-centered and filled with beautiful space images. There are also significant misconceptions related to astronomy from science fiction films. Unless removed, these misbeliefs generally reflect back on our society and do more damage. The GTN project gives science and non-science students a behind-the-scenes look at a research process. Students' quotes about the fact that Andromeda galaxy looks different through a telescope or Uranus is tilted on its side are just some of the examples of such conceptual changes which occurred during this project. Proposal writing where students put in so much effort to find out information about the chosen object which leads to knowing the reality of astronomical objects. Quotes like: "I took this class because I was very interested in learning about zodiacs and horoscopes and stuff like that. I was highly mistaken." This hows how important the GTN project is in giving the right information.

B. Limitations

The GTN project and this analysis was limited in what is can achieve due to various factors as described below.

Authentic research experience:

Despite the fact that this project is based on the CUREs model, it does not give students authentic research experience but rather gives them experience of the process of authentic research. As a result, this project has a limitation to provide that the actual research experience. This GTN project curriculum can only be applied to students of astronomy at the entrance level and would require modification for the higher-level astronomy classes to lead to publishable results.

Observation through telescopes:

The use of robotic telescopes via Skynet software requires constant supervision due to the delicacy of the task. The task of updating Skynet with astronomical object's coordinates requires precision and unless done with care, the telescope could crash. So, a sufficient number of instructors to guide participants through this process are required. The GTN project was not able to let all participants use the Skynet software rather the observations were queued into the software. This disappointment appeared in themes of *changes* and d*islike* categories. Astronomy observations have their own limits related to location, time, weather, etc. These limitations pour into the observation task of the GTN project, where students are unable to observe the desired object. This disappointment appears in the category of *dislike* which affects the overall affective shift of the project.

Data collection:

The qualitative data collection limitation comes from lack of resources and limited time frame to gather qualitative data. The one-on-one interview process is time consuming thus making it almost impossible to gather data in a one-semester long period frame. It requires resources to conduct interviews and the transcription of the verbal interview into text. The GTN project is carried out in a relatively small classroom with a maximum of 20 students so that this curriculum would need major modifications for a larger classroom. In the GTN project as a whole, several assistants would be required to carry out each task with due care and to gather information.

The research study was qualitative thus we only have students' written account in their own words. This project was set out to gain insight into what students feel and experience, so it does not give any quantifiable account of students' learning. Since students are putting their experience into written words, it is limited to student's linguistic skills. This project is limited to giving insight into what participants experienced and may have learned but does not give any accurate insight into exactly what they learned. In order to probe what participants learned, a different tool would be required, for example, to test students' content knowledge or knowledge of the process and practice of science.

C. Future modifications

There are several modifications that can be made to make the GTN project more effective, flexible, and easy to use. These modifications are a result of the analysis of students' written accounts as follows:

1. Provide an optional list of topics which are observable for participants, to avoid disappointments.
2. Students should be able to use the software to operate the telescope as much as possible with the help of the instructor and assistants.
3. Let students communicate about the relatability of what they are learning in class and the project.

4. Constant reminder of guidelines for the project along with its deadlines.
5. Add examples of proposals which students can refer back to. [This change was made, and students found it to be helpful.]
6. Students should have the opportunity to continue the research project the next semester if they are interested.
7. A quantitative analysis to determine how much students have learned.
8. For a larger class create a group project instead of conducting individual projects.

D. Conclusions

CUREs is a good step forward in teaching astronomy for ASTR 101 class and doing a qualitative study about the way we teach ASTR 101 can help improve our curriculum from student's perspective. So far, the CUREs model has proven to positively influence students' learning. This was our attempt at giving students the real-world experience at early on in their college years. Students showed great interest in this project and were excited to learn about astronomy topics. As we can see in Figure 5, the *positive affect* category is higher than any other category by at least 50%. There are very few dislikes or suggested changes for the project. The graph in Figure 5 student showed a more positive affective shift towards GTN projects. Students showed more excitement about observation and using scientific tools like Skygazer, Stellarium and Skynet. The goal of giving a real scientist-like experience was successfully achieved according to the student's quotes in Table 1 and 6. The highlight of the project was peer review, panel discussion, and observation. We are also able to see knowledge of astronomical objects and vocabulary increased during this project.

A qualitatively done study always yields results about shifts in behavior, attitudes, self-efficacy, etc. As we discussed earlier in the methodology section, this project has held the characteristics of grounded theory. The epistemology of learning what astronomers do can only be experienced by an interactive, inquiry-based classroom rather than a traditional lecture and lab-based setting. We can see in the result that constructivism paradigm fits best if the goal is to enhance learning through experience. The GTN CUREs project has provided students with not only scientist-like experiences but also scientific thinking skills and research experience.

The GTN project was done in a small setting classroom so the curriculum for the project as well as the methodological framework might change for other settings. The future step we hope would be to modify the curriculum for various sets of classrooms for different demographics to gain a wide range of qualitative data. This project also has the potential to be a mixed-method research study to evaluate how well students do in a classroom throughout the project. With appropriate modification, this similar framework could also be adopted in any basic physics course to enhance students' ability to do science and their scientific thinking skills and problem-solving skills with appropriate modification.

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