

Redesign of Introduction to Astronomy Lab: Using recent pedagogical research to improve general science education.

SCHOLARSHIP OF TEACHING AND LEARNING GRANT PROPOSAL

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Abstract

The goal of this project is to restructure the Introduction to Astronomy Laboratory course (PHYS 1130L) to emphasize active learning, improve problem solving skills and better educate students in the scientific method. This will be achieved in three principal ways. We will reformat the course to double the time spent in faculty-student and peer interaction. We will rewrite course materials to employ inquiry based learning methods rather than traditional “cookbook” style instruction. We will also add a hands-on learning component utilizing the newly-built Campus Observatory. This will allow us to adopt a research-based teaching methodology, which encourages students to make and interpret their own observations of the physical world.

PHYS 1130L is one of the most popular laboratory courses for non-science majors to meet their general education requirements. Recent research highlights the critical importance of practical astronomy courses because they are often the terminal science experience in a non-STEM student’s educational career. Unfortunately, many students leave university with limited mathematical skills and a poor grasp of scientific concepts. For these reasons we want to maximize the learning experience and teaching quality in this class. To do this we want to test the hypothesis that a greater emphasis on conceptual understanding, interactive learning and active engagement will lead to measurable student learning gains.

We expect to improve the way students understand concepts and solve scientific problems. By emphasizing transferable skills, this course has the potential to better serve the University by improving critical thinking abilities and general scientific literacy.

Budget Request for SOTL Grant Year 2014

Joint Proposal? Yes X No

Title of Project Redesign of Introduction to Astronomy Lab: Using recent pedagogical research to improve general science education.

Duration of Project 1 year

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UNC Charlotte SOTL Grants Previously Received (please names of project, PIs, and dates) none

Allocate operating budget to Department of Physics and Optical Science

Account #	Award	Year One January to June
Faculty Stipend	Transferred directly from Academic Affairs to Grantee on May 15	\$3850
911250	Graduate Student Salaries	
911300	Special Pay (Faculty on UNCC payroll other than Grantee)	
915000	Student Temporary Wages	\$1500
915900	Non-student Temporary Wages	
920000	Honorarium (Individual(s) not with UNCC)	
921150	Participant Stipends	
925000	Travel - Domestic	
926000	Travel - Foreign	
928000	Communication and/or Printing	
930000	Supplies	
942000	Computing Equipment	
944000	Educational Equipment	\$1468
951000	Other Current Services	
GRAND TOTAL		\$ 6818

Attachments:

1. Attach/provide a narrative that explains how the funds requested will be used.
2. Has funding for the project been requested from other sources? Yes X No. If yes, list sources

Budget Narrative

Faculty Stipend

We request faculty stipend for support during summer 2014 for Catherine Qualtrough.

During this time, CQ will be primarily responsible for rewriting the laboratory manual and associated course materials including quizzes and for the installation and testing of observatory equipment (telescopes). She will write SOPs for the safe and appropriate operation of this equipment by students. CQ will also train student teaching assistants who will instruct the indoor labs.

We request \$3850 for CQ. Her nine month part-time salary (20 hours a week) is \$20k. Two months' salary is \$4444. We are therefore requesting the maximum allowable stipend.

CQ is not teaching in the summer nor does she have more than two UNC faculty development grants, as per guidelines.

Total faculty stipends: **\$3850**

Student Temporary wages

One teaching assistant will be trained during summer 2014. We request the student be paid at a rate of \$15 per hour. We plan for the student to commit 10 hours a week for 10 weeks. This totals **\$1500**. This pay-rate is based on the current pay of graduate teaching assistants in our department.

Equipment

We request funds the acquisition of 2 portable optical telescopes (including eyepieces). These will compliment observations made with the Observatory telescope already purchased by the Department and allow more students to be actively engaged in making observations. We also wish to purchase one solar telescope which allows safe daytime observations of the Sun. This is important during early Fall and late Spring when Daylight Saving Time makes it difficult to perform night-time observations during the lab period.

The total quoted for this equipment (as shown in Appendix C) is \$1468 including taxes and shipping.

Total equipment funds requested: **\$1468**

Matching Funds

The Chair of the Department of Physics and Optical Science has agreed to spend \$6500 on a smart-classroom upgrade to the current laboratory teaching space in Burson 114. The Department purchased a new telescope (\$9000) for the observatory in summer 2012, intended for use in PHYS 1130L.

The total in matching funds is: **\$15,500**



Office of the Dean

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November 5, 2013

SOTL Grants Committee Center
for Teaching & Learning
ctl@uncc.edu

Dear Committee Members:

I am writing to endorse the SOTL proposal from Drs. Catherine Qualtrough and Susan Trammel to redesign the Introductory Astronomy Lab. The Department of Physics and Optical Sciences has had good results to date with the redesign of other introductory courses and this is one of the more popular options for non-science majors to meet a lab science requirement.

This proposal is a revision of one that Drs. Qualtrough and Trammel submitted to last year's competition and I supported the proposal at that time. I understand that they have responded to the comments of last year's reviewers to strengthen the proposal and clarify the questions that were asked at that time. The redesign will allow the instructors to make better use of the newly acquired telescope in the observatory and the Department is renovating the instructional space. Given the potential benefit to our students of this project, I strongly endorse the effort and urge you to give it your careful consideration.

Please let me know if you require further information. Thank you.

Sincerely yours,



Nancy A. Gutierrez, Dean
College of Liberal Arts and Sciences

Project Narrative

A. Specific Aims

Overall purpose

Guided by recent pedagogical thinking in astronomy education, we propose to overhaul and redesign the *Introduction to Astronomy Laboratory* (PHYS 1130L) to improve the effectiveness of teaching and learning experienced and to advance general science education to predominantly non-science majors.

Statement of problem

PHYS 1130L has an enrolment of approximately 100 students each semester, the majority of whom are non-science majors. This is frequently the only practical science course taken by these students during their university career.

In its current form, PHYS 1130L is taught in 4 sections, each meeting for in-class instruction every two weeks. When a section is not in class, they are assigned “at-home” activities, which involve self-study. This format has produced a high DFW rate (30% average over the last five semesters) and a lack of engagement that has ultimately contributed to poor student attitudes. There is a deficit of instructor-guided inquiry, no peer-to-peer interaction in at-home assignments, and little feedback on concepts introduced in the assignments. Many students fail to complete “at-home” work and, as a result, learning opportunities are being lost. Students view the goal of the laboratory as an exercise in getting the “correct” answers as quickly as possible. They show limited understanding of the scientific method, inquiry-based observation and data

presentation techniques. Finally, with two weeks between class meetings, students lack a sense of continuity and a chance to effectively build upon concepts throughout the course.

Research question and objectives

We aim to test the following hypothesis:

Greater emphasis on conceptual understanding, interactive learning and active engagement will lead to measurable student learning gains in an astronomy lab setting.

To do this we will redesign PHYS 1130L based on recent pedagogical research and analyze the effect of these changes on student learning outcomes. All proposed changes are intended to introduce more active learning and hands-on activities while engaging students in greater peer-to-peer collaboration and faculty-student interaction. These objectives will be addressed by:

- Eliminating “at-home” lab assignments and requiring weekly student attendance.
- Increasing student-instructor contact time by using a teaching assistant in addition to a more experienced instructor.
- Rewriting the outdated laboratory manual and changing the emphasis from, “getting the right answer” to learning how to use the scientific method to solve problems.
- Incorporation of the newly built UNC Charlotte Observatory, including a new 14” Celestron telescope, for increased outdoor observing opportunities and research based active engagement.

We choose to focus on curricular reform of the laboratory, rather than the associated lecture course (PHYS 1130) for several important reasons:

- A smaller class size (max. 25) enables an effective constructivist approach using proven strategies to improve the learning environment, general scientific literacy and students' reasoning skills.[1]
- The new observatory provides an ideal opportunity for hands-on, cooperative and active learning.
- The astronomy lab's popularity and reach promises the greatest potential gains in student learning and will enable us to contribute to the growing field of pedagogical research on astronomy education.
- Gains in conceptual learning are more easily evaluated, increasing the data set available to the general astronomy education community.

Impacts of this study

The predominantly non-STEM student enrollment provides a vital and often final opportunity to improve scientific literacy, understanding of the scientific process, and attitudes towards science. The popularity of astronomy as a subject of study provides an opportunity to improve students' transferable skills, including critical thinking,[2] numerical data interpretation and problem solving.

By utilizing up-to-date pedagogical research, instructors can improve the way they facilitate student learning and can assess the effectiveness of strategies employed in the classroom.

Our objectives align with the purpose statement of the Department of Physics and Optical Science, which “seeks to provide an environment which preserves and advances learning” and “will offer a variety of courses at the introductory level which are appropriate for the general education requirements of the University”.

Please note, we are resubmitting this proposal after consideration of the committee's recommendations. In particular we have strengthened the way that the impact on student learning is measured. In Section D and Appendix A we describe an evaluation tool that has been applied to the course in its current format, which we will use to evaluate student learning gains in the redesigned course. In addition we have reduced the budget and, as noted in Section G, we are confident that no further funding will be necessary to sustain the redesigned course beyond the life of the grant.

B. Literature Review

Who are our students?

Although much has been published in the field of physics education research (PER), significantly less has been written in the sub-discipline of astronomy education research (AER). While PER focuses primarily on science majors, AER typically involves non-STEM majors, taking a general education course.

Because of its broad appeal, astronomy is a popular subject for study:[3] introductory astronomy courses reach approximately 250,000 college students each year in the US, with 10% of all US college students taking a survey astronomy course.[4] Statistics compiled by the American Institute of Physics suggest that these courses annually enroll as many or more non-science students than introductory courses for non-majors in any other discipline.[5] Particularly significant is the fact that these students represent a large number of future teachers: 40% of students taking introductory science courses intend to become licensed teachers.[6]

Pedagogical motivation for changing the course curriculum and structure

Ultimately, students learn and retain most strongly information from activities that they do themselves, while they retain less of what they hear and what they read about.[7] A national study on the teaching and learning of astronomy in introductory courses showed that the “active learning” strategies we intend to employ can have a positive effect on students’ conceptual gains.[8]

In traditional methods of laboratory instruction, students read a brief description of a phenomenon and are then presented with a set of tasks to complete, not unlike a cookbook recipe.[9] By placing emphasis on a correct “end” result, students often fail to see the relevance of an assignment, and experience confusion and frustration when they find it difficult to finish every task.

Instructors recognize that the development of desirable attitudes toward science is also an important part of science education. There is growing evidence that students who possess such positive attitudes will perform better academically.[10]

To date, only one study has evaluated the effects and challenges of hands-on research based activities (night-time observing) on student learning gains in an introductory astronomy lab course.[11] Our project can directly contribute to this new and growing research area.

What will these improvements offer to our students, teachers and society?

In a recent report, classes that spent 25% or more of their time using interactive learning strategies were found to average more than twice the normalized gain scores of classes that spent less than 25% of class time teaching interactively.[12] These learning gains applied equally to

men and women, across ethnicities and for students of all levels of prior math and science preparation.[12] This highlights the potential for a highly interactive, hands-on lab to improve the way our students learn and strongly supports the development of new strategies in lab instruction. In addition data sets focused on the “Gen. Ed.” student population are vital, since these students will comprise a greater percentage of the professional population than will science majors.

In 2008, the NSF reported that only one quarter of the country’s adults were scientifically literate.[4] Scientific literacy demands a working knowledge of what science is, how scientific knowledge is developed, how to distinguish pseudoscience from valid science, and the limitations of science. Astronomy has many links to related fields, hence providing an ideal way of introducing students to the scientific method and increasing their overall scientific literacy.

C. Methods

The National Science Teachers association recently issued a position statement,[13] which states that laboratory courses must be an integral part of the science curriculum at college level. They must allow students the opportunity to interact directly with natural phenomenon or collected data. Furthermore, all students should have opportunities to experience inquiry-based labs, including opportunities to design investigations, engage in scientific reasoning, manipulate equipment, record data, analyze results and discuss findings.

The restructured lab course will provide more active learning opportunities and allow for the development of hands-on, intuitive understanding using the new campus observatory.

An inquiry-based, team approach is at the core of active learning and these skills are valuable in any career in which problem solving is required. We will therefore change the emphasis from finding the “correct” answer, to learning skills needed to solve problems by designing assignments that mimic the scientific method. The following key elements will be incorporated:

1. **Observe** a phenomenon.
2. **Question** what is occurring.
3. **Predict** an outcome for a new or modified situation based on current conceptual understanding.
4. **Test** evidence via experiment.
5. **Evaluate** by comparing with existing data.

We will require **weekly** in-class attendance and eliminate at-home assignments to improve conceptual learning and peer-to-peer instruction. By running two lab sessions simultaneously we will maintain the current schedule. Each week, one group will do an indoor activity while the other conducts outdoor observations. A TA will supervise the indoor activities while an experienced instructor with formal astronomy training will run the observing sessions. We anticipate that outdoor labs will be conceptually demanding and AER emphasizes the importance of utilizing instructors with specific astronomy education.[4] Existing faculty will train a teaching assistant who will focus on broader principles of physics and math during indoor classes.

As a contingency for bad weather, we have planned indoor labs that address similar concepts as the outdoor labs, utilizing up-to-date online astronomical data resources.

Students are not currently exposed to guided experiential inquiry and although most are enthusiastic about outdoor observing, they are quickly frustrated by the inadequate observing space and outdated equipment, which is difficult to use. We will acquire supplementary equipment necessary to fully utilize the new observatory allowing students to make meaningful observations. To do this we request two additional telescopes for nighttime use. This will increase the amount of time that students can spend making scientific observations and will serve to educate students about the operation of different types of telescope. We also request a solar telescope, which will allow students to safely observe the Sun. These observations reveal sunspots and solar prominences which enable an understanding of the solar cycle and how it affects Earth. This will also address a longstanding problem with the lab; namely that during early Fall and late Spring, the hours of darkness fall outside of the lab period (6:30 p.m. to 9:15 p.m.).

The Department of Physics and Optical Science will provide matching funds for this proposal by upgrading the current teaching space to a “smart classroom,” as well as purchasing the new telescope. These investments enhance our goals and will provide widely usable resources for many years. The campus observatory is an invaluable tool in conducting outreach activities within the Charlotte community and amongst Charlotte area schools. The Observatory held its inaugural “Star Party” event in April 2013. Approximately 20 PHYS1130L students acted as volunteers at the event, and were engaged in: telescope operation, talking to the public (ranging in age from 4-65 years) about stars and planets, performing demonstrations about light pollution and assisting in the setup and running of the event. The overwhelming response from the students was that they enjoyed the event and found that through explaining concepts they solidified what they had learned during the course.

By involving undergraduate student volunteers, we can increase the quality and frequency of events, while encouraging students to share and reflect on their learning.

D. Evaluation

We will use both summative and formative assessment techniques derived from published questionnaires developed by astronomy educators. In anticipation of making the proposed changes to this course and to strengthen our case for their

implementation we have administered a pre-test to students in the Fall 2013 semester of PHYS1130L. This pre-test was designed to gauge students' knowledge base and highlight misconceptions/challenges to be addressed.

It consisted of 15 multiple choice questions (Appendix A) and evaluated four major course goals:

- 1) Students understand basic astronomical concepts.
- 2) Students are able to apply knowledge from astronomy to other situations.
- 3) Students have a good understanding of the scientific method.
- 4) Students understand how to evaluate the quality of scientific knowledge in public discourse

In total 85 students were administered the test and a breakdown of the results in each of the four categories are presented in Figure 1. Only category 3 yielded correct answers from more than 50% of the students.

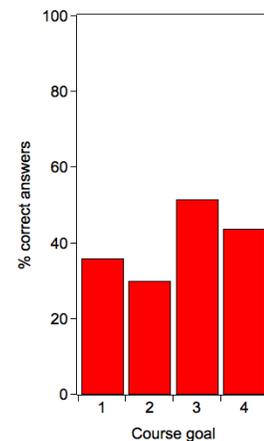


Figure 1. Collected responses to the pre-test administered Fall 2013.

At the end of the course students will take a post-test that is, without students' prior knowledge, identical to the pre-test. Mean pre- and post-scores will be used to calculate normalized student learning gains,[14] which will be compared using appropriate statistical analysis to determine significance.

This will give us a baseline to which any student learning gains after the course reformat can be effectively compared. We will implement the same pre- and post- test to students taking the restructured course.

Our aim is to elevate the number of correct answers in each category above 75% on the post-test.

Formative assessment will provide information needed to adjust teaching and learning activities while the course is ongoing, thus ensuring students achieve targeted learning goals within a set timeframe. Pre- and post-lab quizzes will be administered to evaluate student understanding and we will include observation, discussion with students and course surveys (utilizing a Likert scale) to assess attitudes and impact of the course format. An active learning environment affords more opportunity for immediate student and instructor feedback.

We also plan to adapt existing rubrics designed to test scientific abilities and measure critical thinking skills.[2], [15] An example is presented in Appendix B. The designed rubrics will enlighten students about expectations and be useful for the instructor in evaluating lab reports.

E. Knowledge Dissemination

The ideas of PER and AER are gaining enthusiastic acceptance in departments nationwide. It is crucial that we share our findings with colleagues at UNC Charlotte as well as astronomy and physics education peers at the regional and national level.

The American Astronomical Society (AAS) and the American Physical Society have both endorsed the value of research in astronomy education. The AAS recently stated that “the findings of AER and the scholarship of teaching, when properly implemented and supported, will improve pedagogical techniques and the evaluation of both teaching and student learning,” (<http://aas.org/governance/resolutions.php#edresearch>). This is also demonstrated by the recent growth of the online journal, *Astronomy Education Review* (<http://aer.aip.org>), which we plan to use as a primary vehicle for dissemination of our work.

The University of Arizona’s Center for Astronomy Education (CAE) has developed teaching excellence workshops, which have been offered at universities and at national meetings such as the AAS and the American Association of Physics Teachers. The CAE recently received a NSF grant to create the Collaboration of Astronomy Teaching Scholars.[16] CATS is a large and growing international community working to increase the number of instructors conducting research in astronomy education. These outlets would be ideal targets for sharing our findings and for further increasing our teaching standards.

Publications in the *Journal of General Education* and the *Journal of College Science Teaching* are planned to extend the reach of our work.

F. Human Subjects

We expect this project to have exempt status per university policy.

G. Extramural Funding

Once the course modifications are completed and after purchase of the requested equipment, further funding will not be required to sustain the project beyond the life of the grant. Together

with extramural funding, which will be sought from both private and public sources, the Department of Physics and Optical Science will fund further upgrades to the observatory and laboratory.

Because UNC Charlotte is a Space Grant university, we will also apply to the North Carolina Space Grant consortium's "Informal Education/Public Outreach" program to support our use of the observatory for outreach.

H. Timeline

Spring 2014-Summer 2014

1. Rewrite PHYS 1130L laboratory manual
2. Equipment purchase: telescopes
3. Develop SOPs for new telescopes.
4. Adjust pre-test and post-test (evaluation tools) and rubrics if necessary.
5. Pre- and post-test will be administered to students taking PHYS 1130L in its current format. This will be a baseline to which new lab data can be compared
6. Utilize smart-lab upgrade
7. Train teaching assistant

Fall 2014

1. Begin implementation of new course structure. Students will meet weekly and outdoor observing sessions will occur every two weeks. Teaching assistant will instruct indoor lab activities. New lab manual and testing materials will be used
2. Pre- and Post-tests will be given and analyzed. Results will be compared to previous results.

3. Dissemination

- a. CTL and UNC-Charlotte communications
- b. Present findings in journal articles e.g. *Astronomy Education Review*, etc.

I. Bibliography

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[2] M. L. Allen and D. Kelly-Riley, "Promoting Undergraduate Critical Thinking in Astro 101 Lab Exercises," *Astronomy Education Review*, vol. 4, no. 2, pp. 10-10, Jan. 2005.

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Appendix A

Pre- and post-test questions

Goal 1: Students will understand basic concepts associated with astronomy. We will assess 3-4 basic concepts we think students should master in the laboratory.

1. What causes the different phases of the Moon?
 - a. The change in Moon's distance from the Earth as it moves in its elliptical orbit, changing its apparent brightness.
 - b. The Earth's shadow gradually moving over the Moon's surface.
 - c. The change in the fraction of the Moon that is lit by the Sun.
 - d. The position of the Moon in its orbit around the Earth.

2. What is the energy source for the Sun?
 - a. Thermonuclear fusion in the core.
 - b. Radioactive decay of the nuclei of heavy elements.
 - c. Primordial heat, left behind from when the Sun first formed.
 - d. Heat released by gravitational contraction as the Sun slowly shrinks.

3. Imagine that the Earth's orbit were changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?
 - a. We would no longer experience a difference between the seasons.
 - b. We would still experience seasons, but the difference would be much LESS noticeable.
 - c. We would still experience seasons, but the difference would be much MORE noticeable.
 - d. We would continue to experience seasons in the same way we do now.

4. As viewed from our location, the stars of the Big Dipper can be connected with imaginary lines to form the shape of a pot with a curved handle. To where would you have to travel to first observe a considerable change in the shape formed by these stars?

- a. Across the country.
- b. A distant star.
- c. Moon.
- d. Pluto.
- e. Europe.

Goal 2: Students will be able to apply knowledge from astronomy to other situations. We will assess critical thinking with these questions.

5. Two stars in our sky have the same apparent brightness. If neither of them is hidden behind gas or dust clouds, then we know that they:
- a. May be at different distances, in which case the nearest one must have the greater luminosity.
 - b. May be at different distances, in which case the farther one must have the greater luminosity.
 - c. Must have the same temperature.
 - d. Must be at the same distance away from us.
6. Which of the following would make you weigh half as much as you do right now?
- a. Take away half of the Earth's atmosphere.
 - b. Double the distance between the Sun and the Earth.
 - c. Make the Earth spin half as fast.
 - d. Take away half of the Earth's mass.
 - e. More than one of the above.
7. In a mystery story, the culprit made the following statements when describing the murder scene. Which of the following is the only true statement?
- a. "It was just after midnight, as the new Moon was setting over the western horizon"

- b. “The time must have been about midnight because the full Moon was just setting in the west.”
 - c. “It was about 6pm as the first quarter moon was just setting.”
 - d. “The full Moon was just rising as the Sun set.”
8. It takes light 1.3 seconds for light to travel from the moon to earth and 8 minutes to travel from the sun to the earth. Which of the following statements is true?
- a. The sun is 6.2 times further from earth than the moon.
 - b. The sun is 10 times further from earth than the moon.
 - c. The sun is 0.16 times further from earth than the moon.
 - d. The sun is 0.10 times further from earth than the moon.
 - e. The sun is 370 times further from the earth than the moon.

Goal 3: Students will have an accurate understanding of the nature of the scientific process. We will assess understanding of the scientific method used in the laboratory.

9. Which of the following statements about scientific models is true?
- a. A model tries to represent all aspects of nature.
 - b. A model tries to represent only one aspect of nature.
 - c. A model can be used to explain and predict real phenomena.
 - d. All models that explain nature well are correct.
 - e. All current models are correct.
10. A scientist observes a new phenomenon that disagrees with her explanation or hypothesis. Following the scientific method, she should:
- a. Discard the observations as erroneous.
 - b. Modify her hypothesis.
 - c. Reject those observations that do not agree with the theory.
 - d. Wait until someone develops an adequate explanation before announcing her observation.

11. Which of the following statements about scientific theories is not true?

- a. Scientists cannot take a theory seriously if it contradicts other theories developed by scientists over the past several hundred years.
- b. A theory must make predictions that can be checked by observation or experiment.
- c. A theory is a model designed to explain a number of observed facts.
- d. If even a single new fact is discovered that contradicts what we expect according to a particular theory, then the theory must be revised or discarded.
- e. A theory can never be proved beyond all doubt; we can only hope to collect more and more evidence that might support it.

12. In science, a broad idea that has been repeatedly verified so as to give scientists great confidence that it represents reality is called:

- a. A theory.
- b. A Ptolemaic model.
- c. A Paradigm.
- d. A hypothesis.

Goal 4: Students will understand how to evaluate the quality of scientific knowledge in public discourse using both their knowledge of the nature of science and astronomical concepts.

13. Solar flares and other energetic outbursts from the Sun result in fast moving charged particles being released from the Sun. When these particles reach Earth, they can damage satellites in orbit around Earth, cause disruptions in communications and pose a threat to the safety of astronauts aboard the International Space Station. To help anticipate potential threats, astronomers who study the Sun now give a solar weather forecast. This forecast predicts when high level of solar activity (flares etc.) is likely. What data could you use to predict the solar weather?

- a. Monitor the size of the Sun. When it gets larger it is more active.

- b. Monitor the number of sunspots. More sunspots can indicate a higher level of activity.
- c. Monitor the color of the Sun. When it gets redder it is more active.
- d. Monitor the rotation rate of the Sun. When it speeds up, it throws off material.

14. Global Warming (or climate change) is something you have heard about in the news.

Venus is an example of a planet with a runaway greenhouse effect. Why has the greenhouse effect been much more effective in raising the surface temperature on Venus than upon Earth?

- a. Because the solar wind, the major cause of heating in the greenhouse effect is far more intense at Venus' distance from the Sun and Venus has no magnetic field to deflect the solar wind.
- b. Because carbon dioxide, which traps heat from the planet's surface, is the major component in the very dense Venusian atmosphere while it is only a minor constituent of Earth's.
- c. Because the oceans upon Earth have acted as a thermostat in absorbing much of the heat that would have raised the Earth's temperature significantly.
- d. Because the surface of Venus is much more effective than that of Earth in absorbing solar visible and UV radiation.

15. According to modern ideas and observations, what can be said about the location of the center of the Universe?

- a. The Earth is at the center.
- b. The Sun is at the center.
- c. The Milky Way Galaxy is at the center.
- d. An unknown, distant galaxy is at the center.
- e. The Universe does not have a center.

Appendix B

Formative assessment example rubric

1. Prose

Is clear, concise, correct, unambiguous, original, and formatted. Note that cases of plagiarism will be referred directly to the professor.

0-1 Prose is garbled and nonsensical.

2-3 The meaning is mostly clear but occasionally awkward, short, lengthy, ambiguous, imprecise.

4-5 The writer has restated everything in his or her own words; there is no ambiguity.

2. Data

Are clear, complete, and appropriately presented (e.g., lines are only used to join points on a graph if interpolation and continuity is to be communicated).

0-1 Data are missing or disorganized.

2-3 Data are merely tabulated, minimal explanation, presence/absence of patterns may be recognized.

4-5 Data are tabulated, the absence/presence of patterns is recognized, the presentation communicates proper interpretation.

3. Calculations

Derived quantities are correct

0-1 Absent or incorrect.

2-3 Mostly correct, lacking in attention to significant figures and dimensional analysis.

4-5 Correct, appropriate precision is quoted, units are carried through equations and are consistent throughout.

4. Conclusions

Understands how to interpret the data in a consistent and sensible manner.

Are the conclusions suggested by the data? Do the conclusions address the goals? In the presence of alternate interpretations, is the most correct conclusion drawn? Is the conclusion defensible/justifiable?

0-1 Interpretation weak, missing, incorrect.

2-3 Interpretation is consistent with, but a repetition of, the goal.

4-5 Interpretation is logical and convincing.

5. Accuracy

Lab tasks were performed with care to minimize random errors.

0-1 Tasks were performed hastily, carelessly, incompletely.

2-3 Lab is mostly complete, some thought given to how to achieve good results.

4-5 Lab is complete, accurate, performed with deliberateness and attention to detail.

6. Critical thinking

Understands the purpose/goal of the lab in the correct context.

0-1 Purpose is missing or incorrect.

2-3 Purpose is stated but is drawn from the lab sheets.

4-5 Purpose is stated in the context of astronomy and the scientific method.

7. Procedure

Understands the sequential nature of the procedure.

How does the procedure lead directly to the final result? Can the result be improved upon (i.e., make more believable)? Given a lot more time, how would you change the procedure? Can the data quality/quantity be improved?

0-1 Procedural summary is absent or copied from the lab sheets.

2-3 Procedural summary is paraphrased, concise, flows, tendency to be in cookbook format.

4-5 Procedural summary is paraphrased as a means to an end.

8. Assumptions

Understands the assumptions, simplification, and systematic errors that support the procedure (i.e., why the lab achieves the desired result).

0-1 No recognition of errors or built-in assumptions.

2-3 Recognizes assumptions/errors but is unable to justify an opinion regarding their importance.

4-5 Understands assumptions, can quantify errors.

9. Consequences

Understands the implications of the conclusions.

The lab result can suggest consequences or have a wider applicability. For example, would a conclusion about our Solar System be true for each individual planet (deduction), or is a conclusion a part of a larger body of physical processes (induction)?

0-1 Missing or misguided attempt to extrapolate beyond the stated goal.

2-3 Recognizes a few select applications of the results.

4-5 Broad viewpoint that empowers prediction.

10. Perspective

Understands and employs the verification of the results with an independent authority.

0-1 Verification is missing, incorrect, or copied from the lab sheets.

2-3 Verification is made without reference to its authority.

4-5 Authoritative verification is made, contrasted with alternate viewpoints if applicable.

Appendix C

Vendor quotes.



Quantity	Description	Price	Total
2	 Meade ETX-90 3.5"/90mm UHTC Catadioptric Maksutov-Cassegrain Telescope Kit with Super Plossl 26mm Eyepiece (SKU MDET90UTC) Free Shipping Shipping Restriction USA only	\$399.00	\$798.00
1	 Coronado PST Personal Solar Telescope (SKU CDPST) Free Shipping Shipping Restriction USA only	\$669.95	\$669.95

Need More Information?

If you need help with this order, email our customer service representatives at service@adorama.com

Or call our customer care at **800-223-2500 / 212-741-0052**

Summary

Subtotal:	\$1,467.95
Shipping:	--
Taxes:	--
Coupons:	--
Total	\$1,467.95