Analyzing Individual and Cooperative Electronic Response Systems to Improve Student Learning and Attitudes in Astronomy

Patrick M. Len

Cuesta College

San Luis Obispo, CA

2005-2006 @ONE Carnegie Scholars Program

To be submitted to *Astronomy Education Review* (http://aer.noao.edu/)

Keywords: College non-majors, general, research into teaching/learning, teaching approaches, assessment, electronic response systems.

Version 06.05.16

Table of Contents

List of Tables

Abstract

Electronic response systems ("clickers") are used in introductory astronomy classes as a real-time assessment tool, and to encourage student interaction. Different reward structures for responding to clicker questions are used to motivate individual participation, and/or group collaboration before responding. The impact of two different reward structures on student behavior, learning, and assessment effectiveness is investigated. This study finds that a success-bonus incentive (where individual participation points are doubled when the class attains a threshold success rate) strongly motivated students to collaborate, while a participation-only credit (no success-bonus) incentive resulted in one-third of the students answering individually without collaboration. Students who preferred to answer individually ("self-testers") were found to have more positive attitudes towards astronomy and science, and higher self-confidence in their learning than students who still preferred to interact before answering without a success-bonus incentive ("collaborators"). These collaborators experienced downwards shifts in attitudes and self-confidence, in contrast to the static attitudes and self-confidence of self-testers. The implication is that students with little or no background in science prefer to answer collaboratively rather than independently, and that these students are also negatively impacted by a one-semester introductory astronomy course.

1. INTRODUCTION

Cuesta College has implemented a live, in-class electronic response system (Classroom Response System from eInstruction) for introductory astronomy classes. Students use individually purchased and registered clickers to answer questions with immediate feedback (Duncan, 2005). A multiple-choice question is shown on an overhead projector, and students begin to respond using their clickers, each of which has a keypad with alphabetic choices A-H, that sends its response and a unique identification number via an infrared beam to a central receiver. Signals from the receiver are compiled on a computer, which shows on a digital projection screen the students who have already responded, by highlighting their unique clicker identification number. Information on *which* answer each student has selected is *not* shown, but different color codes indicate whether a student has input their answer, changed their answer, or has selected an answer that is not allowed (e.g., pressing F-H on the clicker keypad when the multiple-choice question has only A-E answers). After the question is "closed" (by the instructor, or automatically by a countdown timer), student responses are tabulated for each multiple-choice selection, and the correct answer is indicated, along with the success rate for the question, and the cumulative success rate for the session (eInstruction, 2001).

In this study, two different types of reward structures for clicker questions were used. *Inquiry* clicker questions (Appendix 1) were intended to elicit student responses without the pressure to answer correctly. Students were given credit for responding to each inquiry question, regardless of whether or not their response was correct. *Review* clicker questions (Appendix 2) were intended to encourage peer-interaction (Green, 2002), as students were credited for responding regardless of the correctness of their answers (as with inquiry questions), but their scores for a given review session would be *doubled* if the cumulative class success rate was 80% or higher (eInstruction, 2001).

The time allotted for inquiry and review questions varied according to their purpose. Inquiry questions were brief and avoided the use of technical terms (unless that was the concept explicitly asked about), and focused on the immediate subject at hand. The time allotted for these questions was no more than one to two minutes. In contrast, review questions were taken from actual quizzes/exams from previous semesters, and focused on analytical thinking. The time allotted for these questions was two to three minutes, and more time was given when it seemed that students had not yet adequately discussed the question in-depth. Allotting more time, or giving hints raised student success rates if a review question was judged "on the fly" to be too difficult. As the cumulative success rate was displayed after each review question, students were aware of their progress towards attaining the 80% threshold for doubling their participation credit. If by the last question it was not mathematically possible for the class to reach the 80% threshold (but would come to within a few percentage points of doing so), students were subsequently motivated by the instructor announcing that the success-bonus would be rewarded anyway if the class was 100% correct in responding to the last review question.

Students were relatively quiet when responding to inquiry (participation-only) questions, with discussion (if any) occurring only between neighboring students. Behavior during review (participation with success-bonus) questions was similar at the start of the semester, until just before the end of the first or second weekly review session, when students collectively realized the importance of the success-bonus incentive in answering correctly. From that point through the rest of the semester, the student interaction during review questions was much more animated, with a marked increase in discussion between neighboring students and within small groups. Some students shouted out for assistance from the rest of the class in answering, while others attempted to coach the rest of the class on how to answer (whether vocally, or by indicating their answer on the overhead projector using, fingers or on the screen using laser pointers). The level of interaction and/or contentiousness during discussion was related to how close the cumulative correct response rate of the class was going to be able to match or exceed the 80% threshold, in order for students to double their participation credit.

This study was conducted to measure how the different reward structures of inquiry and review clicker questions affected class-wide student collaborative behavior. Also investigated was the degree to which students preferred to collaborate, and its impact on their attitudes towards science and learning gains in understanding astronomy concepts.

2. METHODS

2.1 Course Description

Astronomy 10 is a one-semester survey course, with an emphasis on descriptive and conceptual understanding, without explicit use of math, although Math 23 (elementary algebra) is the pre-requisite. Enrollment ranges from 30 to 90 students per class. Clickers have been used in this course since summer 2004; this study was conducted in fall 2005, with an enrollment of 39 students.

Other teaching modes besides clicker use include traditional lecture, multimedia presentations, and peer-instruction worksheets. The laboratory component of this class (Astronomy 10L) is optional, and is a separate adjunct course to Astronomy 10.

2.2 Procedures

Student responses were recorded for a total of 211 clicker questions. There were 111 inquiry questions asked during this semester, intermittently throughout each lecture. There were also 100 review questions asked during this semester, with 5-10 questions at the end of each lecture prior to a quiz or exam.

In order to measure the amount of collaborative behavior that occurred for inquiry and for review questions, students participated in a Self-Report of Clicker Use Survey (Appendix 3) on the last day of class, categorizing themselves either as *self-testers* ("I usually answer on my own, without talking/listening to others"), or *collaborators* ("I usually take into consideration what other students are saying before answering"), for inquiry (participation-only) questions and for review (participation with class success bonus) questions. Of the 36 students who reported their clicker use (and had taken all pre- and post-tests), there were 13 self-testers and 23 collaborators for inquiry questions. For review questions there was only one self-tester, and 35 collaborators, where all 13 inquiry self-testers became review collaborators, and one inquiry collaborator becoming a review self-tester. Since a near-unanimity of the class became collaborators for the review questions, for the purposes of further discussion, *students will be referred to as self-testers or as collaborators based on their inquiry question behavior*. The distribution of self-tester or collaborator students (based on inquiry questions) with respect to gender, or with respect to quiz/exam course points was not found to be statistically significant using chi-square analyses. No other demographical constructs were tested for statistical significance, due to the small size of this class, and the degree of its homogeneity (85% of students described themselves as 23 years old or younger, and 75% described themselves as white (non-Hispanic)).

Student attitudes were assessed using the Survey of Attitudes Towards Astronomy (SATA), a 34-question, five-point Likert scale questionnaire that measures four attitude subscales (Appendix 4; Zeilik & Morris, 2003):

- *Affect* (positive student attitudes towards astronomy and science);
- *Cognitive competence* (students' self-assessment of their astronomy/science knowledge and skills);
- *Difficulty* (reverse-coded such that high-difficulty corresponds to a rating of 1, low-difficulty assessment of astronomy/science corresponds to a rating of 5);
- *Value* (students' assessment of the usefulness, relevance, and worth of astronomy/science in personal and professional life).

The SATA was administered as a pre-test on the first day of class, and as a post-test on the last day of class.

Gains in student learning of astronomy concepts was measured using the Astronomy Diagnostic Test (ADT, version 2.0), a 33-question survey with 21 questions on a broad range of astronomy concepts (based on K-12 science curriculum standards), and 12 demographic questions (Appendix 5; Hufnagel, 2002). The ADT was administered as a pre-test on the first day of class, and then without the demographic questions as a post-test on the last day of class.

Out of the enrollment of 39 students, only 36 students (21 male, 15 female) were present for all pre- and post-tests and surveys (Self-Report of Clicker Use, SATA, and ADT). Results from the three students who had taken the pre-tests, but had not taken the post-tests and surveys were not reported.

An online survey (Appendix 6) was administered mid-semester where students ranked the relative efficacy of inquiry and review questions on a three-point scale, compared to other learning and assessment modes. Of the 36 students who had taken all pre- and post-tests, 24 students completed the online survey.

Pearson chi-square tests and Student *t*-tests (paired or independent) were used to evaluate the statistical significance of results. A $p < 0.05$ result was considered significant, while a $p < 0.01$ result was considered highly significant. A result where $p \geq 0.05$ was considered not significant.

3. ANALYSIS AND RESULTS

3.1 Self-Report of Clicker Use Survey

As described earlier, and shown in Table 1 below, a third of the students preferred to respond individually without collaboration to inquiry questions, while a near-unanimity of students collaborated when answering review questions. The type of reward structure used for these clicker questions (participation only for inquiry, versus success-bonus for review) had a highly significant effect on whether students considered themselves self-testers or collaborators (chi-squared test results: $\chi^2(1,36) = 12.77$, $p < 0.001$).

Because of the uniformity of student behavior in answering review questions, for the purposes of further discussion, the distinction between self-tester and collaborator students will refer to how they responded for *inquiry* questions only.

Table 1. Clicker Question Type for Self-testers and Collaborators

	Group[2]	
Construct	Self-testers	Collaborators
Clicker Question Mode[1]		
Inquiry (participation only)	13	23
Review (participation with success-bonus)	1	35

[1]Chi-squared test results: $\chi^2(1,36) = 12.77$, $p < 0.001$.
[2]For the purposes of further discussion, students will be referred to as self-testers or collaborators based on *inquiry* questions only.

The clicker response rate for each student was calculated by dividing the number of inquiry or review responses received from that student, by the total number of clicker questions of that type (111 inquiry questions, and 100 review questions), making this rate a raw measure of student attendance and attentiveness. The clicker response rate for a group was determined by the arithmetic mean of the individual student clicker response rates for that group.

The correctness rate for each student was calculated by dividing the number of correct responses made by that student, by the total number of responses made by that student. The correctness rate for a group was determined by the arithmetic mean of the individual student correctness rates for that group. Review of Table 2 shows that self-testers had higher correctness rates for review questions than for inquiry questions, and this result was highly significant (paired t-test results: $t(1,12) = -15.7$, $p < 0.001$). Collaborators also had higher correctness rates for review questions than for inquiry questions, and this result was also highly significant (paired t-test results: $t(1,22) = -28.6$, $p < 0.001$). Note that the mean success rates for both self-tester and collaborator responses to review questions were just above the required 80% success threshold in order for the class to double their participation credit.

Table 2. Clicker Response and Correctness Rates for Self-testers and Collaborators

	Self-testers		Collaborators	
Construct	Mean	Std. Dev.	Mean	Std. Dev.
Response Rates				
Inquiry (participation only)	81%	14%	80%	14%
Review (participation with success-bonus)	79%	12%	81%	14%
Correctness Rates				
Inquiry (participation only)	46%[1]	8%	44%[2]	7%
Review (participation with success-bonus)	82%[1]	7%	83%[2]	6%

[1]Paired t-test results: $t(1,12) = -15.7$, $p < 0.001$.
[2]Paired t-test results: $t(1,22) = -28.6$, $p < 0.001$.

3.2 Survey of Attitudes Towards Astronomy

Review of Table 3 shows that collaborators and self-testers did not differ significantly on the pre-tests for each of the four SATA subscales. Furthermore, self-testers did not show a significant change in attitudes from pre-test to post-test for each of the four SATA subscales. However, downward shifts in the mean scores for collaborators were highly significant for both cognitive competence (paired *t*-test results: $t(1,22) = 3.66$, $p < 0.001$), and for value (paired *t*-test results: $t(1,22) = 3.80$, $p < 0.001$).

While self-testers had upward shifts in their mean scores for the same two subscales (cognitive competence and value), these pre-test to post-test gains were not statistically significant. As a result of both the slight upward shifts in self-tester scores in cognitive competence and value, *and* the (significant) downward shifts for collaborators in these two subscales, the differences between self-tester and collaborator post-test scores were significant for cognitive competence (independent *t*-test results: $t(1,34) = 2.51$, $p < 0.05$), and highly significant for value (independent *t*-test results: $t(1,34) = 2.93$, $p < 0.01$).

Table 3. Mean SATA Pre-test and Post-test Scores for Self-testers and Collaborators

	Self-testers		Collaborators	
SATA Subscale	Mean	Std. Dev.	Mean	Std. Dev.
Affect (low = 1, high = 5)				
Pre-test	3.6	0.9	3.6	0.6
Post-test	3.4	0.9	3.4	0.8
Cognitive Competence (low = 1, high = 5)				
Pre-test	3.6	0.8	3.5[1]	0.5
Post-test	3.8[2]	1.0	3.1[1,2]	0.6
Difficulty of Subject (high = 1, low = 5)				
Pre-test	2.8	0.6	2.7	0.4
Post-test	2.9	0.7	2.7	0.5
Value of Subject (low = 1, high = 5)				
Pre-test	3.9	0.6	3.8[3]	0.5
Post-test	4.0[4]	0.5	3.4[3,4]	0.7

[1]Paired *t*-test results: $t(1,22) = 3.66$, $p < 0.001$.
[2]Independent *t*-test results: $t(1,34) = 2.51$, $p < 0.05$.
[3]Paired *t*-test results: $t(1,22) = 3.80$, $p < 0.001$.
[4]Independent *t*-test results: $t(1,34) = 2.93$, $p < 0.01$.

3.3 Astronomy Diagnostic Test

Table 4 illustrates that both self-testers and collaborators showed small pre-test to post-test gains in mean ADT scores. These gains were highly significant for self-testers (paired *t*-test results: $t(1,12) = -3.74$, $p < 0.01$), and significant for collaborators (paired *t*-test results: $t(1,22) = -2.47$, $p < 0.05$). These slight gains on ADT scores have previously been noted as typical for astronomy courses (Alexander, 2005). Self-tester mean scores were significantly higher than collaborator mean scores for both the pre-test (independent *t*-test results: $t(1,34) = 2.43$, $p < 0.05$), and for the post-test (independent *t*-test results: $t(1,34) = 2.61$, $p < 0.05$).

Also seen in Table 4, collaborators had significant pre- to post-test gains in the confidence of their ADT answers (paired *t*-test results: $t(1,22) = -2.44$, $p < 0.05$). In comparison, self-testers also had pre- to post-test confidence gains, but this result was not found to be significant. Self-testers had slightly higher pre-test confidence ratings and post-test confidence ratings than collaborators, but these differences were not significant.

Table 4. ADT Pre-test and Post-test Scores for Self-testers and Collaborators

	Self-testers		Collaborators	
Construct	Mean	Std. Dev.	Mean	Std. Dev.
ADT Scores (21 questions)				
Pre-test	9.1[1,3]	3.3	6.7[2,3]	2.6
Post-test	9.6[1,4]	3.3	6.9[2,4]	2.9
Confidence of Answers (low = 1, high = 5)				
Pre-test	3.0	1.1	2.3[5]	1.1
Post-test	3.5	1.1	2.9[5]	1.1

[1]Paired *t*-test results: $t(1,12) = -3.74$, $p < 0.01$.
[2]Paired *t*-test results: $t(1,22) = -2.47$, $p < 0.05$.
[3]Independent *t*-test results: $t(1,34) = 2.43$, $p < 0.05$.
[4]Independent *t*-test results: $t(1,34) = 2.61$, $p < 0.05$.
[5]Paired *t*-test results: $t(1,22) = -2.44$, $p < 0.05$.

Table 5 summarizes findings from the demographic survey portion of the ADT, which was administered only for the pre-test. Because of the overlapping structure of math course sequences at Cuesta College, responses for question 24 (highest completed math course) could not be mapped to reflect a consistent cumulative math background. Students' math and science experiences were instead inferred from their ADT scores, and from their qualitative level of math and science confidence upon entering this course. Self-testers had rated themselves higher than collaborators as being good at math (question 30), good at science (question 31), and expecting that astronomy would be less difficult (question 32, similar to the SATA difficulty subscale). However, only for question 31 (good at science) was there found to be a significant difference between self-testers and collaborators (independent *t*-test results: $t(1,34) = 2.06$, $p < 0.05$).

Table 5. ADT Pre-test Responses for Self-testers and Collaborators

	Self-testers		Collaborators	
Construct	Mean	Std. Dev.	Mean	Std. Dev.
Pre-test Questions (low =1, high = 5)				
How good are you at math?	3.5	0.9	3.0	0.8
How good are you at science?	3.5[1]	0.9	3.0[1]	0.7
What best describes the level of difficulty you expect from this course? (1 = extremely difficult, 5 = very easy)	3.0	0.8	2.7	0.5

[1]Independent *t*-test results: $t(1,34) = 2.06$, $p < 0.05$.

3.4 Online Survey of Learning/Understanding Efficacy

Of the 36 students in the class, 24 students (eight self-testers, 16 collaborators) took this online survey, rating the degree to which inquiry and review questions helped with understanding the course material (where 1 = "not at all helpful," 2 = "somewhat helpful," 3 = "very helpful"). The rating for traditional lecture by instructor was included for comparison.

As shown on Table 6, self-testers gave higher ratings than collaborators for lecture, inquiry questions, and review questions. The only statistically significant result was in the higher rating given to lectures by self-testers, compared to the lower rating from collaborators (independent *t*-test results: $t(1,23) = 2.10$, $p < 0.05$).

In the second part of this online survey, students rated the degree to which inquiry and review questions tested their understanding of the material. The rating for quiz and exam multiple-choice questions was included for comparison. There were no significant differences between self-testers or collaborators in how they rated quiz/exam, inquiry or review questions.

Table 6. Online Survey Results for Self-testers and Collaborators

	Self-testers		Collaborators	
Construct	Mean	Std. Dev.	Mean	Std. Dev.
Helped Learning (low = 1, high = 3)				
Lecture by instructor	3.0[1]	0.0	2.6[1]	0.5
Inquiry (participation only)	2.9	0.4	2.6	0.5
Review (participation with success-bonus)	2.9	0.4	2.8	0.5
Measured Understanding (low = 1, high = 3)				
Multiple-choice quiz/exam questions	2.8	0.4	2.4	0.5
Inquiry (participation only)	2.8	0.5	2.4	0.5
Review (participation with success-bonus)	2.8	0.5	2.5	0.5

[1]Independent *t*-test results: $t(1,23) = 2.10$, $p < 0.05$.

4. SUMMARY AND CONCLUSIONS

4.1 Summary of Results

The success-bonus structure of review questions (credit for participation doubled if the cumulative class success rate was 80% or higher) strongly affected student clicker use behavior. A near-unanimity of students became collaborators for review questions, up from nearly two-thirds for inquiry questions, and the success rate for review questions increased to just over the 80% success-bonus threshold, up from approximately only 50% for inquiry questions.

Students identifying themselves as collaborators for inquiry questions had significant *downward* pre- to post-test trends for cognitive competence and value attitudes, and their post-test cognitive competence and value scores were significantly *lower* than the post-test scores for self-testers.

Both self-testers and collaborators regarded inquiry questions and review questions as being just as effective as lecture and quiz/exam questions in terms of helping with their learning, and in measuring their understanding.

4.2 Conclusions

Regardless of the differences between self-tester and collaborator attitudes towards science and learning (as discussed below), both types of students had identical success rates in answering inquiry questions. The success-reward structure of review questions very strongly encouraged students to interact and cooperate in responding, resulting in much higher success rates for both self-testers and collaborators in answering review questions, in contrast to less cooperation and lower success rates for inquiry questions.

Self-testers reported higher proficiency in science, and demonstrated a greater background knowledge in astronomy than did collaborators. A possible explanation is that students with more exposure to science would be more motivated to "self-test" their knowledge during inquiry questions. In contrast, students with less exposure to science would be less comfortable answering on their own and would collaborate more before answering. It is plausible that self-testers (with more exposure to learning science than collaborators) would already have well-formed attitudes towards astronomy. In contrast, this one-semester astronomy course (with no science pre- or co-requisite) would make up a large part of the science experience for collaborators, and thus have a much greater (and negative) impact on their attitudes. This is consistent with earlier findings by Zeilik & Morris (2003) that reported "no change" in attitudes for students in an astronomy course with college-level physics as a pre- or co-requisite, noting that one semester of astronomy (after an extensive amount of exposure to science) had little effect on their attitudes towards science.

4.3 Implications for Teaching

The success-bonus reward structure used for review questions motivated a near-unanimity of students to collaborate. This is a striking result for such a simple incentive, and demonstrates that students can be persuaded to interact cooperatively in responding to clicker questions.

In contrast, the participation-only reward structure of inquiry questions sharply divided the class between self-testers and collaborators. Self-testers had more positive attitudes towards science, which remained static from pre-test to post-test, while collaborators had pre-test to post-test *drops* in cognitive competence and value attitudes. The implication is that a one-semester astronomy course has a very large impact on the formation of nascent science and learning attitudes of students without an extensive background in science. The downward shifts in attitudes demonstrated by the collaborators in this study could hopefully be minimized or even reversed in future classes by first using SATA and ADT pre-test scores to identify students with negative attitudes and lack of exposure to science. Since these students would be predisposed towards collaborative behavior, engaging students in this mode using clickers should be made as constructive and meaningful as possible, in order to stimulate positive analytical discussion especially during review questions, rather than passive "herd mentality" behavior. Students already regard clickers as an effective mode of instruction and assessment. The challenge is in maximizing the impact of clickers in fostering beneficial collaborative behavior, while contributing to positive shifts in attitudes towards science and learning.

4.4 Implications for Future Research

The ADT has been previously shown to be an effective diagnostic of student understanding of basic K-12 astronomy concepts (Hufnagel, 2002), but is not an effective measure of the gains in the wider range of topics covered in the typical college astronomy course, as reflected in this study, and as discussed by Bardar *et al.* (2005). Assessment tools to more effectively measure gains in student learning that are currently being developed are the Light and Spectroscopy Concept Inventory (Bardar *et al.*, 2005), and the Star Property Concept Inventory (Bailey, 2006), and future studies using these tests are in progress.

It is suggested that pre-test demographic survey questions be modified to directly measure the amount of students' education in math and science (as opposed to the qualitative assessments of self-efficacy used in this study).

Subsequent investigations should involve a larger student population, and look into the underlying reasons *why* self-testers have positive attitude gains, while collaborators have lower attitudes that have negative gains. Furthermore, students should also be interviewed and/or polled to determine their explicit motivation(s) for reporting themselves either self-testers or collaborators, and how these are correlated with their attitudes towards science and learning. Yet another proposal would be to survey students on the first day of class before using clickers, and periodically as the semester progresses on their current preference for answering inquiry and review questions on their own, or after collaborating, in order to track the evolution (if any) of self-testers to collaborators, and/or *vice versa*.

4.5 Acknowledgements

This research was supported by the 2005-2006 @ONE Carnegie Scholar Program, hosted by Evergreen Valley College (John Whitmer, Mary Wong-Kauzlarich, and Judy Rookstool); Michelle Barton (Palomar College) and Darla Cooper (Oxnard College) provided valuable input and feedback regarding the design and analysis of this research project.

5. REFERENCES

Alexander, W. R. 2005, "Assessment of Teaching Approaches in an Introductory Astronomy College Classroom," *Astronomy Education Review*, 2(3), 178.

Bailey, J., 2006, in preparation.

Bardar, E. M., Prather, E. E., Brecher, K., Slater, T. F. 2005, "The Need for a Light and Spectroscopy Concept Inventory for Assessing Innovations in Introductory Astronomy Survey Courses," *Astronomy Education Review*, 4(2).

Duncan, D. 2005, *Clickers In The Classroom*, Pearson Education.

eInstruction Corporation 2001, *Classroom Performance System (CPS) for the Mac Quick Course Teacher's Guide*, 30.

Green, P. J. 2003, *Peer Instruction for Astronomy,* Pearson-Prentice Hall.

Hufnagel, B. 2002, "Development of the Astronomy Diagnostic Test," *Astronomy Education Review*, 1(1), 47.

Zeilik, M. & Morris, V. J. 2003, "An Examination of Misconceptions in an Astronomy Course for Science, Mathematics, and Engineering Majors," *Astronomy Education Review,* 2(1), 101.

6. APPENDICES

6.1 Inquiry Question Examples

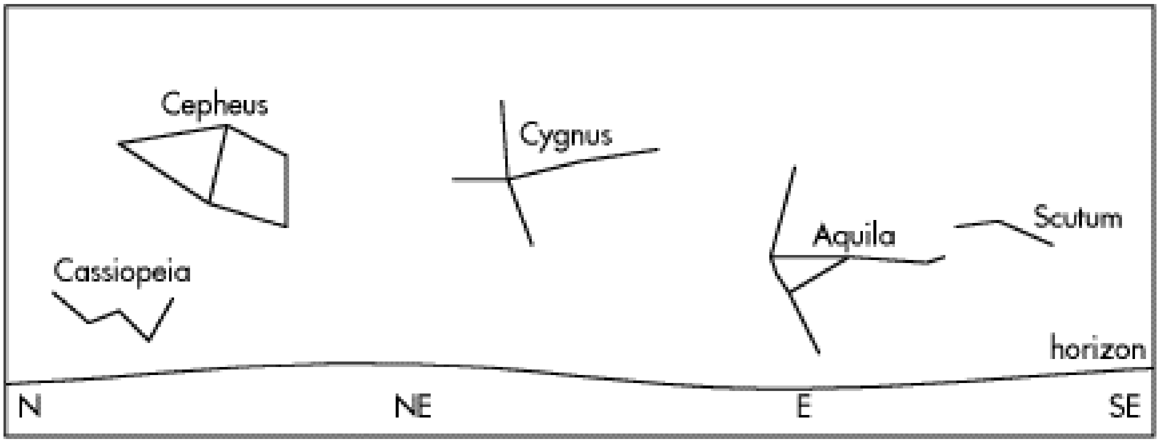
1. The Earth makes one complete rotation about its axis in:
- (A) Approximately four minutes less than 24 hours.
- (B) Within one minute shorter or longer than 24 hours, depending on the time of year.
- (C) Approximately four minutes more than 24 hours.
- (D) Approximately 365.24 days.

2. How did the Moon form?
- (A) It spun off from the Earth during an early stage of formation.
- (B) It formed alongside the Earth.
- (C) It was captured by the Earth.
- (D) It formed from the remnants of a collision that vaporized the outer layers of the Earth.

3. Which type of main sequence star will be the *most* luminous?
- (A) A massive main sequence star.
- (B) A medium-mass main sequence star.
- (C) A low-mass main sequence star.
- (D) The luminosity of a main sequence star does *not* depend on its mass.

6.2 Review Question Examples

For the following question, consider the view of the northeastern horizon shown below, as seen from San Luis Obispo, CA at a certain date/time.



1. Which one of the following statements best describes the positions of these five constellations exactly 24 hours after the date/time shown above?
(A) They will all be slightly lower in the sky, closer to the northeastern horizon.
(B) They will all be in exactly the same place in the sky.
(C) They will all be slightly higher in the sky, farther up from the northeastern horizon.
(D) They will all be somewhere just above the southwestern horizon.
(E) They will all not be visible anywhere above the horizon.

2. Which one of the following choices describes evidence that *contradicts* the giant impact theory of the origin of the Moon?
(A) From radioactive dating, the crust of the Moon is older than the ocean floor of the Earth.
(B) Iron is much less abundant in the core of the Moon than it is in the core of the Earth.
(C) The chemical compositions of the crust of the Moon and the crust of the Earth are very similar.
(D) The surface of the Moon has a higher crater density than the surface of the Earth.
(E) (None of the above choices (A)-(D) would contradict the giant impact theory of the origin of the Moon.)

3. Which one of the following statements best explains why the most massive main sequence stars are also the most luminous main sequence stars?
(A) They have the fastest fusion rates in their cores.
(B) They are the youngest stars.
(C) They contain and release more energy from unstable radioactive isotopes.
(D) They contain and release more energy from gravitational contraction.
(E) (None of the above choices (A)-(D), as the most massive main sequence stars are *not* the most luminous main sequence stars.)

6.3 Self-Report of Clicker Use Survey

Name: ______________________________________ *Date:* ________________

Classroom Performance System Clicker Exit Survey
The questions below are designed to classify your use of the CPS clickers during this semester, specifically distinguishing between inquiry (participation only) questions, and review (participation with cooperation bonus) questions. For each question, select one choice only.

How would you classify yourself as a CPS clicker user for inquiry (participation only) questions?

[ ] I usually answer on my own, without talking/listening to others.
[ ] I usually take into consideration what other students are saying before answering.

How would you classify yourself as a CPS clicker user for review (participation + cooperation) questions?

[ ] I usually answer on my own, without talking/listening to others.
[ ] I usually take into consideration what other students are saying before answering.

6.4 Survey of Attitudes Towards Astronomy (pre-test and post-test)

Name: ____ *Date:* __________________

Survey of Attitudes Toward Astronomy (Pre)
The questions below are designed to identify your attitudes about astronomy and science. The item scale has 5 possible responses; the responses range from 1 (strongly disagree) through 3 (neither agree nor disagree) to 5 (strongly agree). Please read each question. From the 5-point scale mark the response that most clearly represents your agreement with the statement. Use the entire 5-point scale. Try not to think too deeply about each response; there are no correct or incorrect answers.

1. Astronomy is a subject learned quickly by most people.	1 2 3 4 5
2. I will have trouble understanding astronomy because of how I think.	1 2 3 4 5
3. Astronomy concepts are easy to understand.	1 2 3 4 5
4. Astronomy is irrelevant to my life.	1 2 3 4 5
5. I will get frustrated going over astronomy tests in class.	1 2 3 4 5
6. I will be under stress during astronomy class.	1 2 3 4 5
7. I will understand how to apply analytical reasoning to astronomy.	1 2 3 4 5
8. Learning astronomy requires a great deal of discipline.	1 2 3 4 5
9. I will have no idea of what's going on in astronomy.	1 2 3 4 5
10. I will like astronomy.	1 2 3 4 5
11. What I learn in astronomy will not be useful in my career.	1 2 3 4 5
12. Most people have to learn a new way of thinking to do astronomy.	1 2 3 4 5
13. Astronomy is highly technical.	1 2 3 4 5
14. I will feel insecure when I have to do astronomy homework.	1 2 3 4 5
15. I will find it difficult to understand astronomy concepts.	1 2 3 4 5
16. I will enjoy taking this astronomy course.	1 2 3 4 5
17. I will make a lot of errors applying concepts in astronomy.	1 2 3 4 5
18. Astronomy involves memorizing a massive collection of facts.	1 2 3 4 5
19. Astronomy is a complicated subject.	1 2 3 4 5
20. I can learn astronomy.	1 2 3 4 5
21. Astronomy is worthless.	1 2 3 4 5
22. I am scared of astronomy.	1 2 3 4 5
23. Scientific conclusions are rarely presented in everyday life.	1 2 3 4 5
24. Scientific concepts are easy to understand.	1 2 3 4 5
25. Science is not useful to the typical professional.	1 2 3 4 5
26. The thought of taking a science course scares me.	1 2 3 4 5
27. I like science.	1 2 3 4 5
28. I find it difficult to understand scientific concepts.	1 2 3 4 5
29. I can learn science.	1 2 3 4 5
30. Scientific skills will make me more employable.	1 2 3 4 5

31. Science is a complicated subject.	1 2 3 4 5
32. I use science in my everyday life.	1 2 3 4 5
33. Scientific thinking is not applicable to my life outside my job.	1 2 3 4 5
34. Science should be a required part of my professional training.	1 2 3 4 5

Name: ____ *Date:* __________________

Survey of Attitudes Toward Astronomy (Post-Test)
The questions below are designed to identify your attitudes about astronomy and science. The item scale has 5 possible responses; the responses range from 1 (strongly disagree) through 3 (neither agree nor disagree) to 5 (strongly agree). Please read each question. From the 5-point scale mark the response that most clearly represents your agreement with the statement. Use the entire 5-point scale. Try not to think too deeply about each response; there are no correct or incorrect answers.

1. Astronomy is a subject learned quickly by most people.	1 2 3 4 5
2. I had trouble understanding astronomy because of how I think.	1 2 3 4 5
3. Astronomy concepts were easy to understand.	1 2 3 4 5
4, Astronomy is irrelevant to my life.	1 2 3 4 5
5. I got frustrated going over astronomy tests in class.	1 2 3 4 5
6. I was under stress during astronomy class.	1 2 3 4 5
7. I understood how to apply analytical reasoning to astronomy.	1 2 3 4 5
8. Learning astronomy required a great deal of discipline.	1 2 3 4 5
9. I had no idea of what's going on in astronomy.	1 2 3 4 5
10. I like astronomy.	1 2 3 4 5
11. What I learned in astronomy will not be useful in my career.	1 2 3 4 5
12. Most people have to learn a new way of thinking to do astronomy.	1 2 3 4 5
13. Astronomy was highly technical.	1 2 3 4 5
14. I felt insecure when I have to do astronomy homework.	1 2 3 4 5
15. I found it difficult to understand astronomy concepts.	1 2 3 4 5
16. I enjoyed taking this astronomy course.	1 2 3 4 5
17. I made a lot of errors applying concepts in astronomy.	1 2 3 4 5
18. Astronomy involved memorizing a massive collection of facts.	1 2 3 4 5
19. Astronomy was a complicated subject.	1 2 3 4 5
20. I can learn astronomy.	1 2 3 4 5
21. Astronomy is worthless.	1 2 3 4 5
22. I was scared of astronomy.	1 2 3 4 5
23. Scientific conclusions are rarely presented in everyday life.	1 2 3 4 5
24. Scientific concepts are easy to understand.	1 2 3 4 5
25. Science is not useful to the typical professional.	1 2 3 4 5
26. The thought of taking a science course scares me.	1 2 3 4 5

27. I like science.	1	2	3	4	5
28. I find it difficult to understand scientific concepts.	1	2	3	4	5
29. I can learn science.	1	2	3	4	5
30. Scientific skills will make me more employable.	1	2	3	4	5
31. Science is a complicated subject.	1	2	3	4	5
32. I use science in my everyday life.	1	2	3	4	5
33. Scientific thinking is not applicable to my life outside my job.	1	2	3	4	5
34. Science should be a required part of my professional training.	1	2	3	4	5

Instructor-only analysis notes:

Affect subscale questions ("–" denotes a reverse-scaled question):

–5, –6, +10, –14, +16, –22, –26, +27

Cognitive competence subscale questions:

–2, +3, +7, –9, –15, –17, +20, –28, +29

Difficulty subscale questions:

+1, –8, –12, –13, –18, –19, +24, –31

Value subscale questions:

–4, –11, –21, –23, –25, +30, +32, –33, +34

6.5 Astronomy Diagnostic Survey (excerpt)

(Refer to http://solar.physics.montana.edu/aae/adt/ for the complete test; only the pre-test questions used in this study are shown below.)

22. In general, how confident are you that your answers to this survey are correct?
    (A) Not at all confident (just guessing)
    (B) Not very confident
    (C) Not sure
    (D) Confident
    (E) Very confident

24. What was the last math class you completed prior to taking this course?
    (A) Algebra
    (B) Trigonometry
    (C) Geometry
    (D) Pre-Calculus
    (E) Calculus

27. What is your gender?
    (A) Female
    (B) Male
    (C) Decline to answer

30. How good at math are you?
    (A) Very poor
    (B) Poor
    (C) Average
    (D) Good
    (E) Very good

31. How good at science are you?
    (A) Very poor
    (B) Poor
    (C) Average
    (D) Good
    (E) Very good

32. Which best describes the level of difficulty you expect/experienced from this course?
    (A) Extremely difficult for me
    (B) Difficult for me
    (C) Unsure
    (D) Easy for me
    (E) Very easy for me

6.6 Online Survey of Learning/Understanding Efficacy

1. In order to receive credit for completing this survey, enter your four digit ID number: _____

2. How much did each of the following aspects of the class help your learning?

	Not at all helpful	Somewhat helpful	Very helpful	N/A
Lecture by instructor				
In-class activities				
CPS inquiry (participation only) questions				
CPS review (participation + cooperation) questions				
Multimedia movies				
Starry Night (TM) simulations				
Hands-on demonstrations				
In-class interaction with instructor				
Office hours interaction with instructor				
In-class interaction with other students				
Outside-class interaction with other students				

3. How effective were the following in measuring your understanding of the course material?

	Not effective	Somewhat effective	Very effective	N/A
CPS inquiry (participation only) questions				
CPS review (participation + cooperation) questions				
Quiz/midterm multiple choice questions				
Midterm short-answer questions				
Scale used for course grade				

4. How useful were the following resources in studying for this course?

	Not useful	Somewhat useful	Very useful	N/A
Main textbook (Fix, *Astronomy: Journey to the Cosmic Frontier*, 4/e)				
Optional workbook (Adams *et al.*, *Lecture-Tutorials*, 1/e)				
Study guides (from website, for main textbook)				
Sample quiz/midterms (from website)				
Starry Night (TM) files (from website)				
Learning goal weblinks				