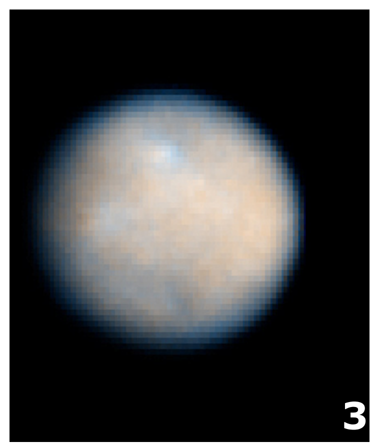
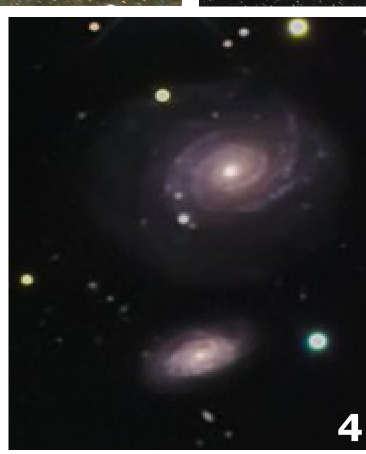
1

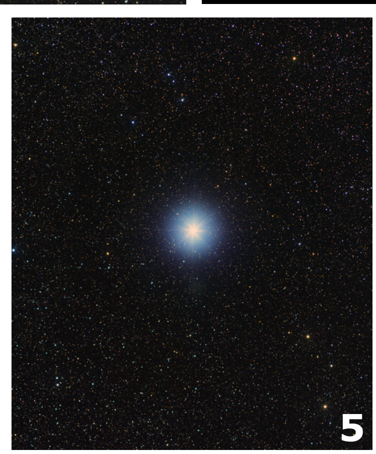
May 2014
Volume 1 Number 1
ISSN 2372-8388

Journal and Review of Astronomy Education and Outreach

A Scholarly Publication of Research, News and Commentary







Journal and Review of Astronomy Education and Outreach (JRAEO)

JRAEO Scope

Articles on any topic relating to educating students or the general public about astronomy are of interest. This can include areas of study often designated as astronomy education or space science education, as well as topics from allied fields such as physics, geoscience, math or history education, as long as the topic is found in an astronomy course or used to excite and inform people about astronomy.

The subject areas include all grade levels–primary, elementary, middle school, and secondary level (in the US, the K-12 system)–undergraduate education (both astronomy majors and general education courses or other domains where astronomy can be included, such as exobiology or cosmochemistry), teacher education, graduate education, and informal or free-choice education involving the general public, including studies of the media (newspapers, social media, etc.) and dedicated facilities such as science centers and planetariums.

Contact

Address: 3605 Sandy Plains Road, Suite 240-203, Marietta, GA 30066
Main phone: +1-404-702-8147 Fax: +1-404-393-7037 Website: www.jraeo.com

Journal and Review of Astronomy Education and Outreach

May 2014 Issue 1
Volume 1 Number 1

Section A – Research

Section B – General Articles

The *Journal and Review of Astronomy Education and Outreach (JRAEO)* [ISSN 2372-8388, online only] is published three times a year, as one volume of three issues. Beginning in 2015 it will be published only during the academic year, without any summer issue. It is published by Hermograph Press LLC (the LLC), 3605 Sandy Plains Road, Suite 240-203, Marietta, GA 30066. http://www.hermograph.com

Subscription price: $45.00 per year (three consecutively numbered issues). Prices are exclusive of tax. The price includes online access to the issue numbers purchased. The Publisher reserves the right to offer some articles free in open access or past the length of time of an embargo (currently 18 months). For other pricing options past Issue 1, which is free to all, including access information, terms and conditions, please contact the Publisher. Note that articles are accepted from any person, but subscribers do not have to pay page fees.

Subscriptions may be ordered and paid for online, via fax, or through postal mail with a check in US dollars drawn on a US bank, by wire transfer or international Money Orders.

Back Issues: Single issues from current and recent volumes are available at the current single issue price of $25, and individual articles may be purchased online as well at varying rates.

Advertising Sales: Inquiries concerning advertising should be forwarded to the Publisher, at the contact information above. Advertising will be accepted as long as it moves forward the astronomy education mission of the publication and does not compete against any specific Hermograph Press product. Acceptance of ads does not constitute an endorsement of the product by the journal or the LLC; placement of the advertising will not be allowed to dictate any editorial control by the advertiser.

Advertising may include professional opportunities.

The LLC reserves the right to refuse any advertisement for any reason.

On the Web: www.jraeo.com (journal)
www.hermograph.com (the LLC)
On Twitter: @JnlRevAstroEdO
On Facebook: Hermograph Press

Welcome…

Larry Krumenaker, Editor

I have to admit that publishing an astronomy education journal wasn't on my bucket list of professional things to do. But fate seems to have directed me to this project. I live my life with both feet unfirmly planted inside the three circles of a Venn diagram. The circles are my work in astronomy (stellar spectroscopy and historical planetary cartography), astronomy education (as researcher, teacher and workshop instructor) and science journalism, as in writing and publishing. Knowledge of all these areas is needed to get an endeavor like this off the ground and running. Already it has been an eye-opening experience.

So let me welcome you to the result of all this experience, the first issue of the *Journal and Review of Astronomy Education and Outreach*, or *JRAEO*. For short we pronounce this Jay-Ray-O, or shorter, Jay-Ray.

This is not the first publication dedicated to astronomy education. We acknowledge the historical place of *Astronomy Education Review*, or *AER*, which ceased publication last year after over a decade run. We stand on that particular giant's shoulder and, indeed, would not have thought to have begun *JRAEO* if it had continued onward. But *AER* is no more, and *JRAEO* will be different in some ways, hopefully seen as advancements by the people in our Community.

For one thing, *JRAEO* will come out on a schedule, three times per year. As a subscriber you will know when you should expect your next issue. That issue will *look* like an issue, and you can print it out and bind it into a packet if you like and store it like a dead-tree edition scholarly journal. *JRAEO* has two sections; Section A is for research articles while Section B is more general articles.

Unfortunately, at least one reason *AER* folded appears to be financial. The days of free, externally supported scholarly publications appears to be over. Yet, unlike other academic publications, we do not have the need to charge hundreds or thousands of dollars in subscription or membership fees. If you can afford the estimable *Sky and Telescope*, or our sister, practitioner publication, *The Classroom Astronomer*, then you should have zero problem affording *JRAEO*.

We have founded this journal with an eye towards quality. To that end we have taken several measures:

1) We have a wonderful, always-contributing group of astronomy educators and outreach specialists as a guiding Editorial and Advisory Board.

2) They and our pool of anonymous peer reviewers—mostly other astronomy educators and researchers—are used in double-blind reviewing. Neither they nor the authors know who is reviewing or being reviewed. All research papers get two (and sometimes even three) of these double-blind reviews. Sometimes we even do a one-person double-blind review for our general articles.

3) We have an official *JRAEO* educational statistician, so if you thought you've correctly fitted everything to a t(-test), he will make sure that you did.

4) This first issue could have been bigger but, in order provide the astronomy education community with a valuable resource, JRAEO is not only committed to maintaining a very high standard for its articles through double-blind reviews, but also with a rigorous editorial process that did not accept all submissions.

So what is it that we will publish? For Section A, we are interested in many types of submissions, not only from other parts of the world but also other related science education domains, such as geoscience or physics education, if they are relevant to an astronomy classroom or to public outreach. It also doesn't matter if it is quantitative, qualitative or mixed methods, as long as the research is done to a high standard. Nor does it have to be classroom oriented. We all know that once formal education ends, informal and life-long learning takes over. Astronomy education (i.e. outreach) occurs for the museum-goer, planetarium visitor, and news reader in magazines or internet browser, or strolling through various public spaces. *JRAEO* wants to report on research and activities in these venues.

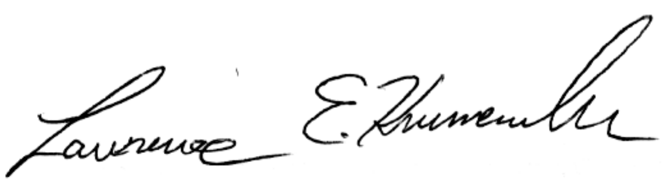
JRAEO will also have a place for more general articles on astronomy outreach and education, Section B. We will accept more general features and interviews, commentary, and ideas and observations that might trigger a good research project for another researcher.

When the question came up, should a journal be created from scratch, I did a lot of research, polling and contacting of many people in the Community. But it was not a project I could do alone. I could not possibly have gotten far without the help of the most fantastic assistant editor one could wish for, Dr. Kristine Larsen. Amiable, capable, diplomatic, and despite 900 miles between us, always within reach of an email or phone call to brainstorm, or go over a submission. I also have a great Board who are active partners, not figureheads, who share ideas, critique constructively and bring more eyes, knowledge and brains to the table than any two persons alone could have.

Our plans are to continue to press forward globally; we have Board members on three continents, and soon, four, when I go next year to Germany. We plan to bring library access to institutions once we have inventory to offer, on both commercial and internet services. Further, we plan to be a visible presence at various astronomy education conferences in the future.

As I hope you can see by this first issue--smaller than the average size that we plan to be in that future--we are seriously striving for a great product, in both the research and general story sections. All of us at *JRAEO*--Editor, Assistant Editor, the Board, and the Peer Reviewers--take this effort seriously. We only ask that the Community of astronomy educators, researchers, and outreach specialists take a look at us and give us a shot. After all, isn't getting published in a high quality astronomy education journal on your professional bucket list?

Sincerely,



Bottom Line for Practitioners, In This Issue:

- In showing the same material in a planetarium dome or on a computer, both show the same amount of learning but long term retention is better with the dome.
- A new instrument for determining student misconceptions and their persistence over time.
- An interdisciplinary project for students using biology and exoplanetary astronomy.
- Assessing learning in an out-of-classroom context by using Moon phases seen in children's literature.
- A 2-dimensional prior knowledge assessment tool idea.

J Rev Astron Educ Outreach Vol. 1 No. 1 pp. 3-4 (2014)

Welcome...

Kristine Larsen, Assistant Editor

My seminal astronomy education experiences, working with the general public and myriad school and social groups while training to be a planetarium and telescope operator as a first semester college freshman, taught me the impact that can be made through free choice learning, both on individuals and society at large. Later, in my faculty position at the same state university, where quality teaching is heavily weighted, I have been quite fortunate to have been encouraged to explore various teaching methods, from writing across the curriculum and online platforms to interdisciplinary courses and flipped classrooms. Sometimes these explorations came about through administrators and supervisors who have urged us to test out these pedagogies, usually after they (not us) had attended some high-priced conference in an exotic location that indoctrinated them on pedagogy Y as THE up-and-coming way to reach our audiences. But these flavors of the year soon faded out of favor with the higher-ups, leaving us here in the trenches, wondering if these techniques are really improving the learning of astronomy. Answering these important questions, therefore, falls into our laps. And in this case, it has fallen, quite literally, into my lap.

Why was I eager to become involved in this project? Much of it boils down to difficulties some colleagues have had in convincing their disciplinary colleagues that astronomy education and outreach research *is* research. If you are taking the time to read this letter, then chances are you clearly understand that the science education research is a scholarly endeavor that is rigorous and has an interested audience. Not only is the scholarship of value for the authors, but its results are also put into practice by the readers. In a perfect academic world, this would not have to be explained or justified – it would be accepted as an obvious fact. However, as we all know, we do not live in such a utopia; we hear voices of disparagement all the time. Until utopia is reached, the community of astronomy education and outreach practitioners and researchers will have to work together to elevate the prestige of what we do. *JRAEO* will play a role in this and I wanted to be a part of the effort to educate those mistaken voices.

There is another, closely related, reason why I strongly feel that this project is an important one. If we are truly committed to recruiting, educating, and retaining the next generation of scientists and science educators, and to creating a generation of citizens that is more science-savvy and less science-phobic than the last, we need to precisely and accurately assess the stated outcomes of our education and outreach programs. We need to know what works, and what does not, and we need to measure in a rigorous manner gains in understanding or attitudes towards science in general, and astronomy in particular. We then need to effectively communicate these results to our peers (including administrators who make important decisions about funding and other resources).

The *JRAEO* I see being formed is going to be the means to these ends. *JRAEO* exists to serve our community by creating a rigorous, peer-reviewed space for the dissemination of relevant, quality research, as well as a forum for informed discussion about these topics. To that end, we are actively looking for your feedback, especially input as to exactly what kind of forum would best suit a productive two-way exchange of ideas. Are you a fan of traditional "letters to the editor," invited point/counterpoint columns, or do you have some new, creative idea? We are listening!

At the moment, I am intrigued and excited by the pieces that are currently working their way through our peer review process, those in this issue and some of which will be appearing in the next issue. The best part of this position is being able to read these pieces before almost anyone else. It is a valuable learning experience for me, personally.

Finally, I want to thank our founding editor, Dr. Larry Krumenaker, for inviting me to be his co-pilot on this voyage of discovery. It's going to be an exciting ride. I look forward to the journey ahead, wherever it takes us.

Sincerely,

COMPARISON OF STUDENT LEARNING ABOUT SPACE IN IMMERSIVE AND COMPUTER ENVIRONMENTS

Laurie Zimmerman and Stacia Spillane, *Houston Independent School District*
Patricia Reiff, *Rice University*
Carolyn Sumners, *Houston Museum of Natural Science*

Received February 26, 2014; Accepted April 25, 2014

Abstract: This paper is the summary of the external evaluation of *We Choose Space,* a 24-minute planetarium show for audiences "who dream of space and wonder about human spaceflight after Shuttle," in which we compared the student learning about space in digital and computer environments immediately afterwards and six weeks later. Paired *t*-tests and an independent *t*-test were used to compare the amount of learning that students achieved on the questionnaire. Interest questionnaires were administered to participants in formal (public school) settings and focus groups were conducted in informal (museum camp and educational festival) settings. Overall results from the informal and formal educational setting indicated that there was a statistically significant increase in test scores after viewing *We Choose Space* in both the portable Discovery Dome (9.75) as well as via the computer (8.88), when tested immediately after viewing. Most importantly, however, long-term retention of the material tested on the questionnaire was significantly better for the students who viewed it in the portable dome over those who learned by computer. Six weeks after viewing the content, the Dome students retained their gains in test scores (10.47), whereas computer-using students had lost most of their gain (3.49), and the improvements over the initial baseline for the computer learners were not statistically significant.

Keywords: students - middle school - space exploration - learning theory and science teaching - assessment - planetarium - immersive - retention

INTRODUCTION

Increasingly, the challenge of engaging youth in learning activities is competing with technology. The average daily time spent with screen media among 8- to 18-year-olds ranks second only to sleeping, increasing from an average of 4 hours and 40 minutes in 1999 to an average of 7 hours and 38 minutes in two decades (Rideout, Foehr, & Roberts, 2010). This impacts education and leads toward the potential expansion of the learning environment.

On another front, a meta-analysis of planetarium efficacy research conducted by Brazzelli & Espinoza (2009) indicated somewhat mixed results in terms of academic performance and/or attitudinal changes toward space science, although overall, the planetarium was found to be more of an effective teaching tool than not.

The positive effect of learning within a portable dome, as opposed to a fixed one, was addressed in an article by Sumners, Reiff, & Weber (2008) that highlighted the expectation that, by providing a direct and visual connection to the subject, higher order learning would accompany the experience. With the use of the portable dome, videos once viewed only in the museum were accessible to a larger pool by offering students access regardless of geographic location.

In his most recent article Jeffery Jacobson (2013) reviewed mastery of learning outcomes based on the communication medium. In addition to a comparison of learning outcomes between those using the computer versus those using the dome, the study addressed the larger question of whether the communication medium made a difference in education, with the contention that every medium provides differences which can be effectively used. Another question is the long term effect of viewing presentations.

Texas has a statewide emphasis on building STEM career awareness. High school students of Rice Engineering and Design Experience (REDE) participating teachers were asked what type of career they wanted to pursue. Over three years, the responses by students that specifically indicated they wanted to pursue space/aerospace or engineering/astrophysics careers increased from 3.4% in 2009-2010 to 6.8% in 2011-2012 (Spillane & Zimmerman, 2012). So in addition to wanting to improve learning outcomes, we were interested in evaluating the affective response with respect to desirability of having a space career.

BACKGROUND

As part of the "Future Space" Project developed with the Louisiana Art and Science Museum, the Houston Museum of Natural Science and Rice University developed programs to be used in a portable Discovery Dome, developed under a prior NASA cooperative agreement (www.eplanetarium.com), and presented both formal and informal learning opportunities for area youth. Funded by NASA under a grant to the Louisiana Art and Science Museum, *We Choose Space* was designed as a 24-minute planetarium show for audiences "who dream of space and wonder about human spaceflight after Shuttle." It was created by the Houston Museum of Natural Science, Home Run Pictures, and Tietronix with scientific oversight by Rice University, and was reviewed by NASA scientists and engineers. Educator Resources accompanied the presentation, including an Educator Guide, Questionnaires, and Activities, developed both by the production team and by teachers in the Rice University Master of Science Teaching program (Sumners et al., 2012). As part of the activities, each lesson was designed using science standards, providing specific directions along with a learning assessment activity. The video, *We Choose Space*, is available to watch in its entirety without charge on the ePlanetarium YouTube channel (*We Choose Space*, 2012).

NASA identified space science education as a method for engaging students in the pursuit of STEM careers, with astronauts seen as role models for students of all ages. They recognized that career choices would be built on experiences that could only happen if students became aware of the programs available and engaged in explorations, either real or virtual. Websites were developed, such as NASA Kids' Club (2013), targeted to appeal to students. The inflatable dome used in the study was a standard mirror-based Discovery Dome designed to hold approximately 25-30 students and used digital projection technology (ePlanetarium, 2014). A photograph of the dome is shown in Figure 1. The portable dome and interactive programs were designed to motivate youth to want to become astronauts and/or assist in solving the challenges in transporting and supporting humans in space and creating products for the next generation of scientists and engineers.

Figure 1. Picture of the portable discovery dome inflated at the public middle school with the dome operator, Dr. Ramkumar Bala, Department of Physics and Astronomy, Rice University.

EVALUATION STRATEGIES AND RESULTS

Evaluation Plan

An external evaluation was undertaken in 2013 to examine student learning and retention of the subject matter presented in the *We Choose Space* video. Student retention in both informal and formal learning settings was compared, as was the effectiveness of the delivery system in the formal setting only, by comparing a sample viewing the video in a portable immersive full-dome digital theater brought to the school to a sample presented the same material using a computer. The evaluation plan and instruments were approved by the participating school district prior to the study being conducted.

Population

In both formal and informal environments, a total of 374 participants, ages 11–17, engaged in the study by taking a pretest and posttest and viewing *We Choose Space*. Of the 374 participants, the informal sample consisted of 104 participants, predominantly boys, also ages 11–17, who attended summer camps held at the Houston Museum of Natural Science during July and August 2013, and 70 middle school students, predominantly girls, ages 11 to 13, who participated in the Sally Ride Festival held at Rice University in October, 2013.

The formal sample consisted of 200 middle school students attending an urban public school in the participating school district. A portable Discovery Dome was brought to the school and 93 students completed the pre/posttests and viewed *We Choose Space* in the dome. An additional 107 students completed the pre/posttests and viewed the video on the computer.

Instrument

A questionnaire was developed using information from the video with the content validity checked by NASA personnel. The instrument was used for all the participants with minor changes in the number of questions presented. In addition to the questionnaires, comments about participants' interest about science and space were collected.

Informal learning environment. In the informal learning environment, the evaluation instrument consisted of 16 multiple-choice items, displayed on one page in which students circled the correct responses (see Appendix A). Each student took the instrument as a pretest upon arrival at the Houston Museum of Natural Science prior to watching the video, *We Choose Space,* in the portable Discovery Dome. The same instrument was administered as a posttest after watching the video at the end of the day at the museum.

Museum personnel were interested in collecting formative data regarding the viewing experience. Therefore, questions for a focus group were developed, administered verbally to the groups, and the results were summarized (see Appendix B). A focus group was held in which participants were asked seven questions of which five centered on the show and two centered on career interest and career choice.

Modification of instrument. Based on feedback from personnel after reviewing the results from the informal learning environment, the questionnaire used for the school was slightly modified from 16 questions to 14 questions. More specifically, when comparing the original 16-question survey to the modified 14-question survey, questions 3 and 9 on the original survey were removed. Furthermore, the responses for question 8 were clarified. The original instrument as well as additional educational resources can be found on the show page at Space Update, Inc. (2013).

Formal learning environment. Because of the need to make it applicable to the educational environment, a comparison of the delivery system (computer vs. portable dome) was used only in the formal learning setting. For the formal learning environment, the evaluation instrument consisted of 14 multiple-choice items (Appendix C). For students who watched *We Choose Space* on the computer, the questionnaire was administered on the computer. For students who watched *We Choose Space* in the portable Discovery Dome, a paper version of the questionnaire was administered. Each student took the pretest the same day. The same instrument was given as the posttest directly after watching the video in the portable dome or on the computer.

To assess their interest in science as well as their overall experience, students took a 25-question interest survey, either online for those who watched the show on the computer or a paper version of the same interest survey for those watching in the portable Discovery Dome. Both multiple-choice and open-ended questions were included (see Appendix D). Of the 25 questions, students answered five that centered on telling something about themselves. The final question addressed their long-term career interest.

To examine long-term retention of the material, a sample of 105 students, of which 58 students had originally watched the video in the portable Discovery Dome and 47 students who had originally watched the video on the computer, were administered the posttest on one of the following days: December 17, 18, or 19. The posttest was the same test that was administered on October 31, 2013. The posttest was administered online for all participants.

Participants Attending Summer Camp at the Houston Museum of Natural Science

Description of study. Five different summer camps were chosen to participate in this study. Four of the five consisted of Boy Scouts who were earning merit badges that included Aerospace, Weather, Space Exploration, and Astronomy. The fifth group was comprised of Girl Scouts. The pretest was given to all of the participants the morning they arrived at the Houston Museum of Natural Science. Participants were post-tested using the same instrument at the end of the day. (In Tables 1 through 4, the numbers are given as percentages of questions answered correctly and the gain is a gain of percentage. All questions were weighted equally. For each student, if the student missed all of the items, the minimum percentage would be 0 and if the student knew all of the items, the maximum would be100.)

Table 1

Summer Camp at the Houston Museum of Natural Science, Results of Paired-Samples T-Test

Pretest		Posttest			95% CI for Mean		
M	*SD*	*M*	*SD*	*N*	Difference	*t*	*df*
66.29	14.94	73.38	17.68	104	-9.96, -4.23	4.91**	103

Note. ***p* < .001 (two tailed).

Data analysis. Table 1 summarizes the results of the analysis. Pre- and posttest results were paired for 104 participants and the differences were evaluated using a t-test for paired samples and eta-squared (η^2). There was a statistically significant increase in the mean student test score from pretest (M = 66.29, SD = 14.94) to posttest (M = 73.38, SD = 17.68), $t(103) = 4.91$, $p < .0005$ (two-tailed). The mean increase in test scores was 7.09. The η^2 statistic (.189) indicated a large effect size (Pallant, 2010, p. 247; Cohen, 1988, pp. 284–287).

Participants Attending the Sally Ride Festival at Rice University

Description of study. An annual event at Rice University, the day-long Sally Ride Festival centers on exposing and interesting middle school girls in science by participating in science and engineering activities. In October, 2013, workshops were available for teachers and parents, and astronaut Barbara Morgan was a speaker.

Due to time constraints caused in part by inclement weather, participants were either pretested or post-tested using the 16-item multiple-choice instrument. An independent t-test was conducted to compare student achievement scores of a group of participants prior to watching *We Choose Space* to a group of participants who had watched the show in a portable Discovery Dome attending the Sally Ride Festival.

Table 2

Sally Ride Festival at Rice University, Independent Samples T-Test

	M	*SD*	*n*	Difference	*t*	*df*
Group A Pre-test	36.74	15.06	41	-19.01, -3.85	3.00*	74
Group B Post-test	48.21	18.29	35			

Note. **p* < .05 (two-tailed)

Data analysis. Table 2 summarizes the results. There was a statistically significant difference in scores when comparing those participants who had not watched the show in the portable Discovery Dome (M = 39.46, SD = 13.87) to those participants who had watched the show and immediately took the posttest (M = 48.21, SD = 18.29, $t(68) = 2.26$, $p = .027$). The magnitude of the difference in the means was moderate ($\eta^2 = .069$) (Pallant, 2010, p. 243; Cohen, 1988, pp. 284–287).

Participants at a Public Middle School

Description of study. Students attending an urban public middle school in the participating school district took part in this study as part of their science curriculum. A total of 93 students in grades 6-8 saw the show, *We Choose Space*, in a portable Discovery Dome, and took a pretest prior to watching the show and a posttest after watching the show along with an interest and career survey. The hard-copy, one-page instrument consisted of 14 multiple choice questions and was administered as both the pretest and the posttest. The interest survey consisted of a hard-copy, one-page instrument with 25 multiple choice and open-ended questions administered after the posttest. A total of 107 grade 6-8 students took the pretest prior to watching the show on the computer, and took the posttest as well as the interest survey online after watching *We Choose Space*.

Long-term retention was evaluated by administering to a sample of 105 students from the original 200 an online 14 multiple-choice posttest in December, approximately 6 weeks after students watched *We Choose Space*. The middle school student population is 61% eligible for free or reduced lunch and primarily underserved minorities (African American: 33.3%, American Indian: 1.3%, Asian: 5.8%, Hispanic: 57.5%, and White: 2.2%).

Data analysis. The October formal learning environment pretest and posttest results were paired for 200 students and the differences were evaluated using a t-test for paired samples and η^2, the numbers being given as the percentages of questions answered correctly. The coefficient α for the 14-item posttest was .70, reflecting appropriate internal consistency, especially given the low number of items (Nunnally, 1978). There was a statistically significant increase in the mean student test score from pretest (M = 52.21, SD = 19.46) to posttest (M = 61.50, SD = 21.00), $t(199) = 7.07$, $p < .001$ (two-tailed), that gain being a gain in percentage. The mean increase in test scores was 9.29 (SD = 18.48). The η^2 statistic (.200) indicated a large effect size (Pallant, 2010, p. 247; Cohen, 1988 pp. 284–287).

LONG TERM AND INTER-FORMAT DATA ANALYSES

We wanted to analyze the results in more depth, to see if there were time and format interactions and significance. We examined the results with two mixed methods ANOVA tests. The first mixed between-within subjects analysis of variance was conducted to assess the impact of two different delivery formats (computer, portable dome) on participants' scores on the questionnaire across two time periods (pre-test and post-test). There was no significant interaction between delivery type (computer, portable dome) and time, Wilks' Lambda = 1.00, $F(1,198) = .11$, $p = .74$, partial-$\eta^2 = .001$. There was a substantial main effect for time, Wilks' Lambda = .80, $F(1,198) = 49.83$, $p < .001$, partial-$\eta^2 = .20$, with both groups showing an increase in pretest to post-test scores (see Table 3). The main effect comparing the types of delivery format (computer, portable dome) was not significant, $F(1,198) = 1.20$, $p = .29$, partial-$\eta^2 = .006$, suggesting no difference in the effectiveness of the two delivery formats, computer and portable dome, when both are done immediately around the learning event (Pallant, 2010, p. 282).

Table 3

Public Middle School Students, Pre-Post Test Scores for 'We Choose Space' by Delivery System, October

	Computer (N = 107)		Portable Dome (N = 93)	
Time Period	M	SD	M	SD
Pre-Test	53.67	20.64	50.54	17.97
Post Test	62.55	21.45	60.29	20.52

The second mixed between-within subjects analysis of variance was conducted to assess the impact of two different delivery formats (computer, portable dome) on participants' scores on the questionnaire across a longer timeframe, from pretest and six-week follow-up (see Table 4). There was no significant interaction between delivery type (computer, portable dome) and time, Wilks' Lambda =.98, $F(1,103) = 2.47$, $p = .12$, partial-$\eta^2 = .02$. There was a main effect for time, Wilks' Lambda = .91, $F(1,103) = 9.92$, $p < .05$, partial-$\eta^2 = .09$, with both groups showing an increase in pretest to posttest scores. The main effect comparing the types of delivery format (computer, portable dome) was significant, $F(1,103) = 4.93$, $p = .029$, partial-$\eta^2 = .046$, suggesting there was a difference in the effectiveness of the two delivery formats, computer and portable dome, meaning better retention via the portable dome delivery system (Pallant, 2010, p. 282).

Table 4

Public Middle School StudentsPre-Post Test Scores for 'We Choose Space' by Delivery System, Long Term Retention

	Computer (N = 47)		Portable Dome (N = 58)	
Time Period	*M*	*SD*	*M*	*SD*
Pre-Test	60.49	21.88	50.12	15.57
Post Test	63.98	23.31	60.59	17.15

The numbers are given as the percentages of questions answered correctly, and the gain as gain in percentage. For the students who had watched the show on the computer, the long-term gain was only 3.49 (compared to the short-term gain of 8.88) while students who watched the show in the Discovery Dome had a statistically significant long-term gain (10.47) that was actually slightly larger than their short-term content gain (9.75). Thus, not only did the students who watched the show in the Discovery Dome learn more, they retained it far better than those watching the show on a computer.

Student Interest and STEM Careers

Formal Learning Environment. To assess the effectiveness of the video *We Choose Space* on interest about learning about space and STEM careers, we gave the students a 25-question interest survey. Of the 194 students that answered the question, 150 (77.3%) liked the video and 44 (22.7%) did not like the video. Figure 2 summarizes what students liked best about the video based on a 4-point scale where 1 was *Little* and 4 was *Great*. The majority of students liked when the video talked about the future of the Moon (3.21). This was followed by the way the space station was built (3.12), and what it would be like to live and work on the Moon (3.01).

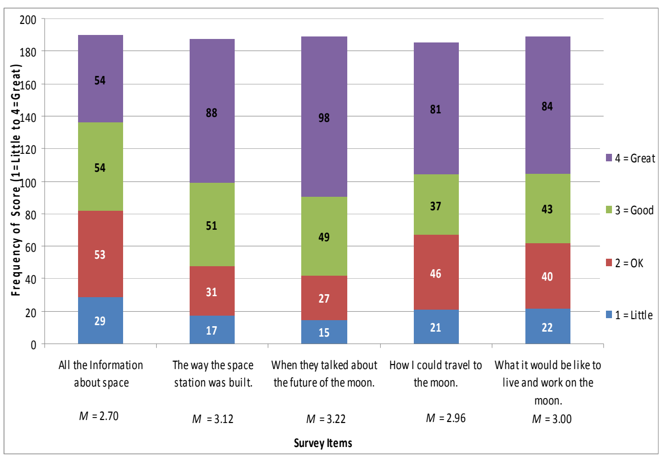


Figure 2. Bar graph showing score distributions (4-point scale, where 1 = Little and 4 = Great) for five survey items answering the question, "What I liked best about the video." Means for each are below the x-axis.

Out of six different items, the highest percentage of students indicated that after viewing the video, they wondered what it would be like to live on the Moon (69.4%), while 64.7% wanted to know more about how to live in space, and 60.2% wondered what it would be like to live on the International Space Station (see Table 5).

Students were asked what they would like to know more about after viewing the video. Of the three selections, space travel received the highest percentage with 59.6%, followed by the Moon (57.1%), and lastly, space careers (25.5%). There were 28 students that provided an additional response. Eleven students wanted to learn more about living on the Moon/life in a dome/building an interplanetary lab, or the International Space Station. Six students wanted to know more about astronauts, space, astronomy, space food, or NASA.

A total of 64 students provided at least one response regarding what they liked or did not like about watching the video in the portable dome. Ten of the responses centered specifically on the dome experience. Comments included, "I liked that it looked 3-D, and we didn't have to wear glasses;" "I like it because it motivated me to learn more about space;" and, "I like how you move to see what's happening, and that it's dark in here."

Table 5

Interest Survey Results: After Viewing 'We Choose Space'…

	N	Yes	No	Maybe
Do you want to know more about space travel?	190	46.3	13.7	40.0
Did you want to know more about how to live in space?	190	64.7	16.8	18.4
Did you wonder what it would be like to live on the moon?	186	69.4	13.4	17.2
Would you want to be a space traveler?	185	33.5	31.9	34.6
Did you wonder what it would be like to live on the space station?	186	60.2	20.4	19.4
Did you wonder what it would be like to live under a dome?	189	51.3	26.5	22.2

Students were asked if they were more interested in space science after watching *We Choose Space*. Out of 184 students who responded to the question, 43.5% indicated *Yes*. When asked if they would like to study more about the Moon and space, 42.2% of 185 respondents indicated *Yes*. Approximately 34% of the respondents indicated that they wanted to learn more about becoming a scientist, while 35% expressed an interest in a career in space science (Table 6).

Students were asked what career they were most interested in pursuing. Out of 198 responses, 102 selected a Science, Technology, Engineering, or Mathematics career, while 12 students specifically indicated a career as an astronaut, aerospace engineer, astronomer, or working at NASA. Sixty-eight students chose non-STEM careers (e.g. musician, professional athletes, law enforcement, and lawyers).

Table 6

Interest Survey Results: After Today…

	N	Yes	No	Maybe
Are you more interested in space science?	184	43.5	25.0	31.5
Do you want to study more about the moon and space?	185	42.2	20.0	37.8
Would you be interested in a career in space science?	184	34.8	36.4	28.8
Did it make you want to learn more about being a scientist?	182	34.1	39.6	26.4

Informal Learning Environment. Five focus groups were held at the conclusion of the day's activities. Participants were asked whether they were interested in pursuing a career in space science. Out of 68 participants that answered the question, 18 or 26% indicated that they were interested in pursuing a career in space science. Participants were asked what career they were interested in pursuing. A total of 39 indicated they were interested in a STEM career while four indicated they were interested in a career as a space scientist, isolation specialist, launching satellites, or studying space health. Five indicated that they were interested in non-STEM careers.

CONCLUSIONS

This study reflects a continuation of a previous study conducted by Sumners et al. (2008). In the current study, the expansion of the environments and long-term retention was measured. Overall results from the informal and formal educational settings indicated that there was a statistically significant increase in test scores after viewing *We Choose Space* in the portable Discovery Dome as well as viewing with the computer. All students who were in the long-term retention group in December took the posttest online, making the evaluation method for collecting the data the same. Since this was the first time that a video was viewed in the portable dome at the school, there is a possibility that this could have affected the results. Therefore, further research is indicated to determine the reliability of this finding.

When examining the long-term retention by delivery format, those students who viewed the show in the dome also had statistically significant increases in test scores, but those students who viewed the show on the computer did not have statistically significant increases. The increase in test scores post – pretest were virtually the same after six weeks for Dome participants as they were just after watching the show in the dome, whereas the students who watched on the computer retained less of their post-show gain in scores. Thus the Dome is a powerful way to not only spark interest, but to help promote learning retention. Possible reasons for this increased retention may be the novelty of the dome environment, fewer distractions in an enclosed environment, and longer-term memory storage from multiple sensory inputs (e.g. direct and peripheral vision).

REFERENCES

Brazzelli, B., & Espinoza, S. (2009). Meta-analysis of planetarium efficacy research. *Astronomy Education Review,* 8(1), 010108. doi: 10.3847/AER2009033

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

ePlanetarium. (2012). *We Choose Space*. [Video file]. Retrieved on 23 March 2014. http://www.youtube.com/watch?v = oC0qS4mHfbs

ePlanetarium. (2014). *Planetarium Domes*. Retrieved from http://www.eplanetarium.com/domes.php

Jacobson, J. (2013). Digital Dome Versus Desktop Display: Learning Outcome Assessments by Domain Experts. *International Journal of Virtual and Personal Learning Environments* 4(3), 51-65. doi:10.4018/jvple.2013070104

NASA. (2013). NASA Kids' Club. Retrieved from http://www.nasa.gov/audience/forkids/kidsclub/flash/#.UsdM-NJDu1g

Nunnally, J.O. (1978). *Psychometric Theory*. New York, NY: McGraw-Hill.

Pallant, J. (2010). *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS for Windows (4th ed.).* Maidenhead, UK: Open University Press/McGraw-Hill.

Rideout, V., Foehr, U., & Roberts, D. (2010). *Generation M2: Media in the lives of 8- to 18-year-olds*. A Kaiser Family Foundation Study. The Henry J. Kaiser Family Foundation (KFF) - Publications. Retrieved from http://kff.org/other/report/generation-m2-media-in-the-lives-of-8-to-18-year-olds/

Spillane, S. & Zimmerman, L. (2012). *Rice Engineering Design Experience (REDE) Final Evaluation Report for 2010-2012*. Houston, TX: Rice University.

Sumners, C., Reiff, P., & Elvert, J. (2012). *We Choose Space*. Retrieved from http://www.spaceupdate.com/?shows/ddome/we_choose_space/we_choose_space.html

Sumners, C., Reiff, P., & Weber, W. (2008). Learning in an immersive digital theater. *Advances in Space Research*, *42*, 1848-1854. doi: 10.1016/j.asr.2008.06.018

Laurie Zimmerman is a researcher in the Houston Independent School District and the corresponding author. Her email address is laurie.zimmerman42@gmail.com**.**

APPENDIX A

We Choose Space! Questionnaire

Your responses will assist in the overall evaluation. Please complete by ***circling the letter next to*** *your answer choice for the 16 questions. After finishing the questionnaire return it to the Evaluator. Thank you.*

1. Which U.S. President announced, at Rice University that we would travel to the moon?
a) John F. Kennedy
b) Lyndon B. Johnson
c) Dwight D. Eisenhower
d) Richard M. Nixon

2. Which country was the first to put a human into space?
a) The United States
b) Italy
c) The Soviet Union
d) Japan

3. A young Earth was formed from which of the following?
a) accretion
b) condensation
c) planetesimals
d) all of the above

4. Which of the following theories is the accepted idea of how our moon formed?
a) fission
b) impact
c) capture
d) co-formation

5. Which celestial object is responsible for Earth's tides?
a) Sun
b) comets
c) Moon
d) asteroids

6. What is the duration of time an astronaut typically stays on the International Space Station?
a) 6 months
b) 6 weeks
c) 6 days
d) 6 years

7. What is the main source of power for the International Space Station?
a) nuclear power
b) solar power
c) rocket fuel
d) oxygen

8. The areas that contain trapped ice on the Moon are:
a) the poles
b) the near side
c) the far side
d) the craters

9. Sixty five million years ago Earth had an impact with what type of object that destroyed over half of all species?
a) comet
b) meteor
c) planet
d) asteroid

10. What energy fuel on the moon could power tomorrow’s nuclear fusion reactors on Earth?
a) hydrogen
b) solar
c) helium 3
d) oxygen

11. The flying human in the lunar habitat is most like
a) an eagle
b) a bat
c) a flying squirrel
d) a moth

12. Creating a human-rated habitat on the moon will likely be
a) expensive
b) difficult to construct
c) not in the near future
d) all of the above

13. If someone is born on and grows up on the Moon, what might happen if they visit Earth?
a) they will be stronger and have weaker bones than folks who grew up on Earth
b) they will be weaker and have weaker bones than folks who grew up on Earth
c) they will be stronger and have stronger bones than folks who grew up on Earth
d) they will be weaker and have stronger bones than folks who grew up on Earth

14. One of the most important things that we have learned from the space program is
a) that Earth is the planet best suited for us to live in so we should take care of it
b) that the Moon would be easy to colonize
c) that a space station can be created quickly and inexpensively
d) that we should use up all our oil on energy and not develop solar energy

15. How does the gravity on the Moon compare to the gravity on Earth?
a) less gravity on the Moon
b) more gravity on the Moon
c) the same amount of gravity
d) there is no gravity on the Moon

16. How often is there a sunrise on the space station?
a) every 24 hours
b) every 90 hours
c) every 24 minutes
d) every 90 minutes

APPENDIX B

The Houston Museum of Natural Science

Focus Group Questions

1. What did you think of *We Choose Space*?
2. What was the best part of your experience?
3. Which programs did you like better and give at least one reason?
4. What is one thing you learned?
5. Is there anything more you would like to know about?
6. After viewing the movie *We Choose Space*, how many of you are interested in knowing more about a career in space science? How many of you are interested in pursuing a career in space science?
7. What careers are you interested in pursuing?

APPENDIX C

We Choose Space! Questionnaire

Your responses will assist in the overall evaluation. Please complete by ***circling the letter next to*** *your answer choice for the 14 questions. After finishing the questionnaire return it to the Evaluator. Thank you.*

1. Which U.S. President announced, at Rice University that we would travel to the moon?
   a) John F. Kennedy
   b) Lyndon B. Johnson
   c) Dwight D. Eisenhower
   d) Richard M. Nixon

2. Which country was the first to put a human into space?
   a) The United States
   b) Italy
   c) The Soviet Union
   d) Japan

3. How often is there a sunrise on the space station?
   a) every 24 hours
   b) every 90 hours
   c) every 24 minutes
   d) every 90 minutes

4. Which of the following theories is the accepted idea of how our moon formed?
   a) fission
   b) impact
   c) capture
   d) co-formation

5. Which celestial object is responsible for Earth's tides?
   a) Sun
   b) comets
   c) Moon
   d) asteroids

6. What is the duration of time an astronaut typically stays on the International Space Station?
   a) 6 months
   b) 6 weeks
   c) 6 days
   d) 6 years

7. What is the main source of power for the International Space Station?
   a) nuclear power
   b) solar power
   c) rocket fuel
   d) oxygen

8. The areas that contain trapped ice on the Moon are:
a) the craters near the equator
b) the near side
c) the far side
d) the craters near the poles

9. What energy fuel on the moon could power tomorrow's nuclear fusion reactors on Earth?
a) hydrogen
b) solar
c) helium 3
d) oxygen

10. The flying human in the lunar habitat is most like
a) an eagle
b) a bat
c) a flying squirrel
d) a moth

11. Creating a human-rated habitat on the moon will likely be
a) expensive
b) difficult to construct
c) not in the near future
d) all of the above

12. If someone is born on and grows up on the Moon, what might happen if they visit Earth?
a) they will be stronger and have weaker bones than folks who grew up on Earth
b) they will be weaker and have weaker bones than folks who grew up on Earth
c) they will be stronger and have stronger bones than folks who grew up on Earth
d) they will be weaker and have stronger bones than folks who grew up on Earth

13. One of the most important things that we have learned from the space program is
a) that Earth is the planet best suited for us to live in so we should take care of it
b) that the Moon would be easy to colonize
c) that a space station can be created quickly and inexpensively
d) that we should use up all our oil on energy and not develop solar energy

14. How does the gravity on the Moon compare to the gravity on Earth?
a) less gravity on the Moon
b) more gravity on the Moon
c) the same amount of gravity
d) there is no gravity on the Moon

APPENDIX D

Future Space Program

Student Survey

Your answers to this survey will be used for evaluation of the program and will not affect your grade in any way. Read the items and mark your answer. After you complete all the survey questions, please return all the materials to your teacher. Thank you!

Please circle the letter corresponding to your answer in the box below.

1. What did you think of the video *We Choose Space*?

A	I liked it	B	I didn't really enjoy it

Because (write a reason)

2. How would you rate seeing *We Choose Space* in the Dome using a 4-point scale?

A	1 Little	B	2 Ok	C	3 Good	D	4 Great

3. What did you like or not like about viewing We Choose Space in the Dome?

Circle the letter corresponding to your answer choice. Please indicate how strongly you agree or disagree with the following statements.

What I liked best about the video…		**Little**	**OK**	**Good**	**Great**
4.	All the information about space.	A	B	C	D
5.	The way the space station was built.	A	B	C	D
6.	When they talked about the future of the moon.	A	B	C	D
7.	How I could travel to the moon.	A	B	C	D
8.	What it would be like to live and work on the moon.	A	B	C	D

Answer the following questions by circling the letter corresponding to your answer choice.

After viewing this video …		**Yes**	**No**	**Maybe**
9.	Did you want to know more about space travel?	A	B	C
10.	Did you want to know more about how to live in space?	A	B	C
11.	Did you wonder what it would be like to live on the moon?	A	B	C
12.	Would you want to be a space traveler?	A	B	C
13.	Did you wonder what it would be like to live on the space station?	A	B	C
14.	Did you wonder what it would be like to live under a dome?	A	B	C

Share something you wonder about.

Please circle all that apply. After viewing this video, I want to learn more about…

15.

A	Space travel	B	The moon
C	Space careers	D	Other_________________________

Please circle all that apply. After viewing this video, how would you find out more about it?

16.

A	From a book	B	Search internet	C	Ask a teacher	D	Other____________________

Please circle the letter that corresponds to your answer.

After today		**Yes**	**No**	**Maybe**
17.	Are you more interested in space science	A	B	C
18.	Did it make you want to learn more about being a scientist?	A	B	C
19.	Do you want to study more about the moon and space?	A	B	C
20.	Would you be interested in a career in space science?	A	B	C

Give a reason why you would or would not be interested in a career in space science?

Please circle the letter corresponding to your answer that tells us something about you.

21. I am:

A	Female	B	Male

22. I'm in grade:

A	5	B	6	C	7	D	8
E	9	F	10	G	11	H	12

23. I'm scheduled for the following class during this time.

A	Science	B	Math	C	Technology	D	Other_________________________

24. For High School I would like to attend __________________________________

25. The career I am most interested in ______________________________

A DIRECT EXAMINATION OF COLLEGE STUDENT MISCONCEPTIONS IN ASTRONOMY: A NEW INSTRUMENT

Andrej Favia[1], Neil F. Comins[1], Geoffrey L. Thorpe[2], and David J. Batuski[1], *University of Maine*

Received April 22, 2014; Accepted May 21, 2014

Abstract: This is the first in a series of papers in which we examine the persistence of 215 common misconceptions in astronomy and suggest correlations among them in an effort to improve the effectiveness of astronomy instruction. Each misconception is based on a commonly-held incorrect belief by college students taking introductory astronomy. At the University of Maine, the course is taught in alternating semesters by Neil F. Comins and David J. Batuski. A total of 639 students over six semesters between 2009 and 2013 completed a survey based on these misconceptions. The survey is a new instrument in that it permits one to indicate either endorsement or rejection of each misconception at various stages in one's life. We present *two versions* of the survey: one in which all statements are presented as misconceptions, and one in which both true and false statements are presented. We test the validity of the survey data and present a preliminary analysis of the data for both versions of the survey. We show that the length of the survey and the presentation order of the statements are unlikely to affect the data. We also show that the reported degree of misconception endorsement may be affected by the phrasing of the statements, that is, whether or not the statements are all false or a mixture of true and false statements.

Keywords: students - non-science majors - general astronomy - Astro 101 - misconceptions - undergraduate education

INTRODUCTION

Since the 1980s, the process of how students learn concepts related to perceptions of motion, the colors of objects, and heat, among many other topics, has been studied, with the subjects of the studies ranging from children to adults (Anderson & Smith, 1988; diSessa, 1982; Flavell, Green, & Flavell, 1986; Kempton, 1987; Posner, Strike, & Hewson, 1982; Sadler, 1998; White, 1982; Vosniadou, 1994; Vosniadou & Brewer, 1992). These studies draw four conclusions about the learning process. First, learning is a complex process that has no "one size fits all" rule on how to teach the relevant material to the class. Second, students in the class may retain any one of a multitude of inappropriate models to explain their observations of relatively simple physical phenomena. Third, misconceptions are strongly-held incorrect beliefs, so much that, as Vosniadou (1994) states, instructors are encouraged "to understand [the misconceptions] and to take them into consideration in the design of instruction" (p. 66). Fourth, these studies support a growing body of research (Clark, Kirschner, & Sweller, 2012, and references therein) showing that, despite the pedagogical efforts of a wide range of instructors in the field, misconceptions in astronomy remain persistent.

The effect of misconceptions on understanding astronomy concepts has been analyzed in a number of studies including Bailey, Prather, Johnson, and Slater (2009), Sadler et al. (2010), Vosniadou, Vamvakoussi, and

---

[1] Department of Physics and Astronomy
[2] Department of Psychology

Skopeliti (2008), and Wallace, Prather, and Duncan (2011). We note in particular that Bailey et al. (2009) assessed pre-instructional ideas about stars and star formation held by 2,200 non-science majors taking an introductory astronomy course (‘pre-instructional’ in this case meaning prior to starting the course). Bailey et al. observed that students often bring misinformation to the classroom (e.g., a star is a “burning ball of gas”). In multiple studies, Vosniadou et al. have shown that children develop and retain the misinformation and, from it, form one of many possible “synthetic models,” e.g., regarding the Earth-Sun system (Vosniadou, 1994) and the formation of stars (Vosniadou et al., 2008).

One approach to assessing how much students learn during instruction about a particular topic is the development of pretests and posttests (e.g. as in the aforementioned studies) to serve as probes for measuring learning. The use of a pretest immediately before instruction and a posttest immediately after instruction presents a controlled environment. In fact, the vast majority of the aforementioned studies rely on recording student responses to a predetermined set of guided questions. An example of a multiple-choice test designed with such questions in mind is presented by Sadler (1998). Sadler successfully implemented a 47-item multiple-choice test to examine the nature of misconceptions held by students primarily in high school. Sadler had acquired sufficient knowledge of student misconceptions in astronomy to design questions in the multiple-choice test, with distracter-driven questions that directly target the misconceptions.

While pretests and posttests administered by themselves immediately before and after instruction (those which are not part of a longitudinal study) provide meaningful information about short-term retention of information, these tests cannot provide information on the persistence of misconceptions over a longer period. Delayed posttests have been used in several studies within an educational research setting (Lombardi, Sinatra, & Nussbaum, 2013; Prather et al., 2004). These tests provide support for conducting studies in educational research in which the data are acquired months after the pretest.

To address specifically the persistence of misconceptions, one ought to study the long-term effects of instruction. As Vosniadou (1994) reminds us, one *should* be well informed of the misconceptions. Instead of designing and implementing a multiple-choice pretest, an alternative approach to analyzing student misconceptions in astronomy is to administer a comprehensive inventory of statements, each phrased in the context of a particular misconception, and ask the students to consider each belief directly. Such a design provides students with the opportunity to give real-time feedback. The design also allows the option for students to indicate approximately when, in their lives, they harbored a misconception, or still endorse it even after instruction in the course, or simply indicate if they have never heard of it before. This last option is generally not provided on multiple-choice tests.

The design of retrospective studies, however, is subject to some issues regarding reliability. Memory is a reconstructive process (Olson & Cal, 1984). As Henry, Moffitt, Caspi, Langley, and Silva (1994) note, a retrospective approach may be of questionable validity in some contexts, notably in the recall of personally-significant emotional and psychosocial material. The authors suggest that “the use of retrospective reports should be limited to testing hypotheses about the relative standing of individuals in a distribution” (p. 92). A comprehensive review by Brewin, Andrews, and Gotlib (1993), however, “suggests that claims concerning the general unreliability of retrospective reports are exaggerated” (p. 82). The likelihood of inaccurate responses may be significantly reduced by asking subjects to provide reports on a timeline for abandoning misconceptions. Hence, in the design of a survey-like instrument, we present brief statements to the students and ask them to respond to the statements directly. Such responses are less likely to be vulnerable to inaccurate self-reports than those associated with the recall of emotionally-significant information across students' lifespans. At the time of this writing, no comprehensive retrospective analysis has been performed on student misconceptions in astronomy.

The purpose of this research is to study the misconceptions that students bring to the college astronomy classroom; the focus of our research is on students enrolled in the introductory astronomy course at the University of Maine from the Fall 2009 to Fall 2013 semesters. The core of this research is the development and implementation of a comprehensive inventory of misconceptions in astronomy. The goal of the study is to analyze the inventory responses to determine an optimal way to present topics in astronomy that ameliorates the misconceptions most effectively. Our research project involves an in-depth analysis of the persistence of misconceptions held by these students in various topics in astronomy, such as stars, the solar system, the Moon, the Earth, other planets in our solar system, the Sun, galaxies, and black holes. The contribution of this research to the field of astronomy education is to inform astronomy instructors on the nature of students' misconceptions, so that instructors may know how to target misconceptions in astronomy more effectively. We begin our analysis in this paper, the first in a series, by presenting a new instrument with which we gather our data to achieve these goals.

METHOD

We developed a new survey consisting of an inventory of statements, presented as short beliefs (e.g., "all stars are white," "Saturn's rings are solid"), spanning all topics in astronomy. From an initially larger item pool, we selected 215 misconception-based statements organized by topics; these statements are presented in Appendix A. Associated with each statement is a unique label for statement in astronomy (sA). For example, the abbreviation for "statement in astronomy number 106" is "sA106." There is no significance to the labels other than for identification purposes. When the actual inventory was administered to the students, the labels were omitted. *The list of 215 items comprises the Astronomy Beliefs Inventory* (ABI). The ABI measures the extent to which students endorse any of these beliefs. The ABI also allows the student to indicate if the student had heard of any of the beliefs prior to college. The ABI was made available to students taking the introductory-level astronomy lecture at the University of Maine, on a voluntary basis for extra credit. In sections taught by co-author Neil F. Comins (NFC), students who opted out were allowed to write an essay for equivalent extra credit. On average, students who volunteered to respond to the ABI required about one hour (a two-hour timeslot was provided). Further along, we will examine the effect of student fatigue on the reliability of the ABI data.

In this section, we outline the development and administration of *two versions* of the ABI. The ABI was administered at the end of each of six semesters at the University of Maine: Fall 2009, Fall 2010, Fall 2011, Fall 2012, Spring 2013, and Fall 2013. The total sample size for all six semesters is N = 639, of which 341 students are male, and 297 students are female. Demographic information is available for all but one student. The average age of the sample is M = 20.0, SD = 3.8 years. The minimum age is 17, and the maximum age is 62. Seven students were at least of age 40, and 30 students were at least of age 25. Respectively, the percents of subjects whose ethnicities are Caucasian, Native American, Hispanic, Asian, African-American, and other/unspecified are 84.6%, 2.0%, 1.9%, 1.4%, 0.9%, and 8.8%. Instructors for the course are NFC and David J. Batuski (DJB). Table 1 presents a summary of the ABI administrations, with the formats (I and II) to be discussed shortly.

Table 1

Administrations of Misconception-Based Statement Lists, Per Semester

Semester	Instructor	Class Size	Sample Size	Statement Count	Format
Fall 2009	NFC	188	114	267	I
Fall 2010	NFC	175	107	235	I
Fall 2011	NFC	171	91	235	I
Fall 2012	NFC	170	91	235	I
Spring 2013	DJB	192	126	235	II
Fall 2013	NFC	174	110	235	II

As noted in Table 1, the course was taught by either of two instructors. Each instructor employs a slightly different teaching pedagogy. In lecture, NFC teaches his students in the context of those particular misconceptions most commonly endorsed by his students, the awareness of which he has developed from his long-term teaching experience (Comins, 2001, 2014). To inquire of the misconceptions held by his students, at the end of each class, NFC asks a misconception-based attendance question about a topic to be lectured in the subsequent class. That is, the question is asked before the related topic is discussed. For example, if the question is "How many zodiac constellations are there?" then the subsequent lecture would include a discussion about zodiac constellations.

In lecture, DJB teaches the material by presenting facts in a traditional manner. In following this traditional framework, DJB places less emphasis than NFC on explicitly announcing common misinformation held by the students during lecture. DJB takes attendance by the use of clicker questions, which ask the students to provide feedback on various concepts in astronomy in real time. The use of such clicker questions has been previously used in astronomy classrooms at other universities (Prather & Brissenden, 2009). The study by Prather and Brissenden promotes the use of clicker questions and claims that they improve (i) student understanding of course concepts and (ii) exam scores. The use of multiple-choice clicker questions whose response options are designed around *a priori* knowledge of common misconceptions held by college students has also been shown to be "an effective method of instruction" (LoPresto & Murrell, 2011, p. 22). In the course taught by DJB, the clicker questions are not usually misconception driven, although misconceptions are frequently involved or probed.

By 2001, NFC had sufficient data on student misconceptions in all general topics pertaining to astronomy (Comins, 2001, 2014) to teach to his students in the context of the misconceptions. In 2009, NFC administered a preliminary list of 267 statements (nearly all of which are false) to his students. Many of the items in the original item pool were eliminated due to issues with clarity, while a few new statements were added; the revised inventory consisted of 235 items. Two versions of the inventory were developed. The first version consisted of either 235 or 267 false statements, depending on the semester. Students were asked to indicate (on Scantron sheets) approximately when in their lives they believed each statement, if ever, or have never heard of it before. Students were also encouraged to write a correction to any statements they did not believe. Directions for completing the first format (Format I) of the inventory are presented in Table 2. A second version of the inventory was later developed, as discussed in the subsequent paragraph.

Table 2

Directions for Completing Format I of the Inventory

A) After the number for each statement please write:

A if you believed it only as a child
B if you believed it through high school
C if you believe it now
D if you believed it, but learned otherwise in AST 109

If you never thought about a certain statement, please consider it now.

Write **E** if the statement sounds plausible or correct to you.
Write **F** if you never thought about it before, but think it is wrong now.

B) If you believe a statement is wrong, please briefly correct it in the space below.

A special format of the inventory was used for the Spring 2013 and Fall 2013 semesters. Directions for completing the second format (Format II) of the inventory are presented in Table 3.

Table 3

Directions for Completing Format II of the Inventory

For each statement, ***first decide if the statement is true or false.***
After you have decided:

If you think the statement is ***true****, enter:*
A if you learned this before high school,
B if you learned this in high school,
C if you learned this in AST 109,
D if you never considered this statement before today.

If you think the statement is ***false****, enter:*
E if you learned this before high school,
F if you learned this in high school,
G if you learned this in AST 109,
H if you never considered this statement before today.

In the second format (Format II), of the 215 statements under consideration, 129 statements were phrased as false, and 86 statements were phrased as true. For the purposes of our analysis, a false statement is a statement phrased as a misconception (e.g., sA111, “Earth's axis is not tilted compared to the ecliptic”), and a true statement is a statement that is scientifically accurate (e.g., “Earth's axis is tilted compared to the ecliptic). Often incorrect statements were made “correct” simply by reversing their direction. In addition, the sequence of the statement presentation was randomized, and three different random-order forms (designed #1, #2, #3) were presented to the students. All three forms contained the same statements, just presented in different sequences.

The advantage of administering Format II is that the mixture of true-false statements eliminates much of the bias introduced from an instrument in which nearly all statements were false. By comparing the responses to the two formats, we were able to test the data of the ABI for convergent validity.

A master code was developed for all responses to the first and second formats of the inventories. The motivation for the codes is the desire to preserve the sense of "timeline," as to approximately how late in one's life does one abandon a misconception. We developed three codes, 1, 2, and 3, which indicate relative degrees of misconception *retainment*, where we define retainment as the tendency for students to hold on to a misconception from either their childhood or during some point in the course. A code of "1" means a student disabused oneself of a misconception as a child or adolescent and so indicates the lowest relative degree of misconception retainment. A code of "2" means a student may have harbored a misconception but unlearned or otherwise got rid of it by the end of the course. A code of "3" means a student still believes the misconception, which indicates the highest relative degree of misconception retainment. These codes are summarized in Table 4. That students may report and then recall disambiguation of a misconception as far back as one's own childhood may prompt a criticism as to whether or not students are providing accurate reports of their own beliefs. As we will show in a later paper, however, there is little concern for the accuracy of these reports, because reports on the ABI are comparable to that of instruments designed in a more traditional multiple-choice format.

Table 4

Codes for Three Relative Degrees of Misconception Retainment

1	unlearned the incorrect belief as a child or adolescent, indicating the lowest degree of misconception retainment
2	unlearned the incorrect belief as a result of taking AST 109, indicating a medium degree of misconception retainment
3	retained the incorrect belief even after instruction in AST 109, indicating the highest degree of misconception retainment

Note that in Format II of the ABI, 86 of the 215 statements under consideration were changed from incorrect to scientifically accurate, as discussed on page 5. Hence, for a scientifically accurate statement such as "the Milky Way is one of many galaxies" (associated with sA218), if a student believed this while a child or adolescent, then the student's response was coded "1." If the student learned this from taking the course, then the student's response was coded "2." If the student did not believe the correct statement, then the student's response was coded "3." This procedure applied to the remaining scientifically-accurate statements in Format II of the ABI.

TESTING THE VALIDITY OF THE ABI

Scoring the Data

The ABI is an instrument originally designed by NFC to assess when, in the lives of students, they unlearned various misconceptions in astronomy. Responses to the ABI partly depend on accurate self-reports. The ABI is also a rather lengthy instrument, in which students are asked to provide accurate self-reports of 215 statements. To analyze our data, we first quantified the data by using the master codes in Table 4, then we computed the mean misconception retainment score for each student, which is the mean over the responses to all statements. To calculate the mean misconception retainment score for each student, we summed over the misconception retainment scores (1, 2, 3) for each item on the inventory, then divided the result by the number of items to which the student responded. The range of possible scores for each student is from 1 to 3, where students with scores between 2 and 3 tend to endorse misconceptions even after instruction, and students with scores between 1 and 2 tend to dispel misconceptions prior to or during instruction. Of the total sample, 89% of the students responded to all 215 statements under consideration, and 98% of the students responded to at least 212 of the statements.

To assess the relative difficulty of the statements, for each statement, we calculated the mean "score" using all of the student responses, already coded as degrees of misconception retainment (Table 4). Statements with a higher overall degree of misconception retainment are associated with misconceptions that are harder to dispel. The overall degree of misconception retainment, for each of the 215 statements, is also reported in Appendix A. Statements with scores between 2 and 3 are associated with misconceptions that are relatively difficult to dispel, and statements with scores between 1 and 2 are associated with misconceptions that are relatively easy to dispel. For example, the overall degree of misconception retainment for sA1, "all of the stars were created at the same time," is 1.60, whereas the overall degree of misconception retainment for sA2, "there are 12 zodiac constellations," is 2.13, indicating that the misconception associated with sA2 is, on average, harder for students to dispel than the misconception associated with sA1.

The histogram in Figure 1 shows the distribution of the misconception retainment scores, presented in Appendix A. The distribution is a continuum from 1, which represents the lowest degree of retainment, to 3, which represents the highest degree of retainment. Misconceptions with retainment scores much closer to 2 than the extremes tend not to be readily dispelled, except through instruction. Examples of such misconceptions are "the Sun is hottest on its surface," with a retainment score of 2.02, and "sunspots are constant fixtures on the Sun," with a retainment score of 1.97. These misconceptions are so close to 2 that they almost equally likely to persist until one is instructed otherwise.

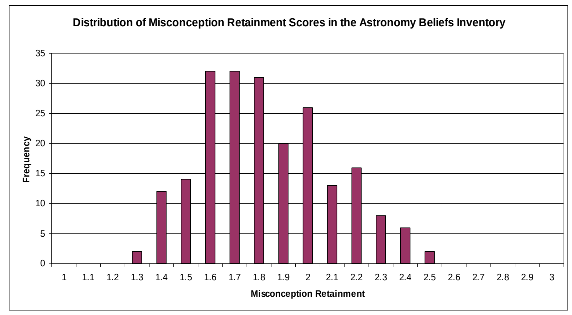


Figure 1. Distribution of misconception persistence scores ("retainment"). Average is 1.88, SD = .266.

Effect of Statement Presentation Order

We introduced Format II of the inventory (the directions of which are in Table 3) to address criticisms regarding statement presentation order. In the Spring 2013 semester, of the three different orders of statements, 42 students received form #1, 43 students received form #2, and 41 students received form #3. In the Fall 2013 semester, 36 students received form #1, 36 students received form #2, and 38 students received form #3. If presentation order plays a significant influence on the responses to the ABI, then one form would have significantly different responses, either for a particularly topic of the ABI or for the entire instrument, than other forms.

To discern whether or not any of the three forms had significantly different scores from the others, we performed independent ANalysis Of VAriance (ANOVA) tests on the three different random orders, *for each topic of the ABI*. The scores under consideration consist of the overall degree of misconception retainment, per student, averaged over the items for each individual topic of the ABI. For our analyses, the topics of the ABI are treated independently and are *not* combined together, so that one ANOVA test is performed per topic, within each semester. According to French, Macedo, Poulsen, Waterson, and Yu (2008), ANOVA "tests for the difference in means between two or more groups" (p. 1), while Multivariate ANalysis Of VAriance (MANOVA) considers two or more *dependent* variables to quantify the difference in means. For the purpose of our analyses, each topic of the ABI is treated independently, and, for each topic, we consider only one variable, the overall degree of misconception retainment, averaged over exclusively the items within it. Therefore, we have elected to conduct ANOVA tests on our data.

We now briefly describe a few important statistical parameters regarding the ANOVA test. The Levene statistic, W, measures the deviation in the homogeneity of variances in the scores and is considered a relatively robust statistic compared to similar statistics (Borkowski, 2014; Hole, 2013). Associated with the Levene statistic is the significance p_V in the differences in the variances, which represents how often one would obtain a value of at least W for the Levene statistic by chance. The F-ratio is the ratio of the variance of the scores between groups vs. the variance of the scores within groups. Associated with the F-ratio is the usual p statistic, which explicitly determines if the means among the groups are significantly different from each other. Values of $p < .05$ are considered statistically significant and are marked with an asterisk (*). These values are significant, because they indicate that there is at least a one in 20 chance of being incorrect when drawing the conclusion that the means are significantly different. Because of the number of univariate comparisons (18 in total, with nine topics for each semester, see Table 5), there is naturally the possibility that one test result may be statistically significant by chance. To employ a less-conservative p value, one may apply a Bonferroni correction (Bland & Altman, 1995), which is an adjustment for the p value based on the number of tests. For a single univariate test, we set the cutoff at .05, whereas for K tests, a statistically significant result on a test would occur if $p < .05/K$, according to the Bonferroni correction.

An additional statistic, however, is needed to assess the tendency to obtain a significant result given the limitation of the available sample size (Walker, 1985, pp. 348-349). The magnitude of the difference among the means for each group, relative to the overall variation in the data, is called the effect size. A small effect size represents a significant effect that is more likely to be detected with a larger sample size, whereas a large effect size represents a significant effect that is relatively easy to detect even with a smaller sample size. Note that one does not actually need a significant result to calculate the effect size. In an ANOVA test, several measures are used to calculate the effect size (Becker, 2000; Cohen, 1988), of which η^2 and ω^2 are summarized here. A common estimation of the effect size is given by η^2 equaling $SS_{Between}$ / SS_{Total} where $SS_{Between}$ is the sum of squares between individual groups, SS_{Within} is the sum of squares within the groups, and SS_{Total} is the sum of these quantities. The estimate η^2 of the effect size is considered small for $0.010 < \eta^2 \leq 0.059$, medium for $0.059 < \eta^2 \leq 0.138$, and large for $\eta^2 > 0.138$. Because η^2 measures only the sample and not the actual population, one accounts for variation within groups to minimize the bias in the estimator. The revised estimator ω^2 of the effect size is given by

$$\omega^2 = \frac{SS_{Between} - df_{Between} \times MS_{Within}}{SS_{Total} + MS_{Within}} \qquad \text{where} \qquad MS_{Within} = \left(\frac{SS_{Within}}{df_{Within}}\right)$$

is the mean square of the data within groups, and *df* is the degrees of freedom. We report both η^2 and ω^2 to estimate effect sizes as appropriate. It is possible that, for some not statistically significant results, ω^2 may become negative, which essentially means that the effect size is negligibly small.

Table 5

Significance of Differences Among the Three Random Sequences of ABI Statements, with Terms as Defined in the Text

	Spring 2013							
ABI Topic	Mean	Std. Dev.	*W*	p_V	*F*(2, 123)	*p*	η^2	ω^2
Stars	1.93	0.25	0.474	.624	1.403	.250	.022	.006
Solar System	1.86	0.32	1.261	.287	3.048	.051	.047	.032
Moon	1.79	0.28	0.367	.693	3.935	.022*	.060	.044
Three Planets	1.81	0.32	0.669	.514	1.450	.239	.023	.007
Earth	1.92	0.27	0.782	.460	1.320	.271	.021	.005
Sun	2.00	0.27	0.657	.520	3.026	.052	.047	.031
Galaxies	1.83	0.32	1.994	.141	1.929	.150	.030	.015
Black Holes	2.01	0.29	0.944	.392	1.990	.141	.031	.015
General Astrophysics	2.10	0.25	0.046	.955	1.528	.221	.024	.008
All 215 Statements	**1.91**	**0.25**	**0.625**	**.537**	**2.567**	**.081**	**.040**	**.024**

	Fall 2013							
ABI Topic	Mean	Std. Dev.	*W*	p_V	*F*(2, 107)	*p*	η^2	ω^2
Stars	1.93	0.26	0.107	.898	0.036	.965	.001	-.018
Solar System	1.87	0.30	1.744	.180	0.450	.639	.008	-.010
Moon	1.81	0.29	0.353	.704	0.279	.757	.005	-.013
Three Planets	1.77	0.33	0.522	.595	0.706	.496	.013	-.005
Earth	1.88	0.26	0.306	.737	0.065	.937	.001	-.017
Sun	2.00	0.25	1.199	.305	0.244	.784	.005	.003
Galaxies	1.82	0.35	0.313	.732	0.001	.999	.000	-.019
Black Holes	2.10	0.30	0.065	.937	0.094	.910	.002	-.017
General Astrophysics	2.07	0.26	0.816	.445	0.526	.593	.001	-.009
All 215 Statements	**1.91**	**0.25**	**0.126**	**.882**	**0.102**	**.903**	**.002**	**-.017**

Having outlined the statistical variables, we are now ready to present our results. Table 5 presents the significance of differences in overall degree of misconception retainment for each of the three forms, in the Spring 2013 and Fall 2013 semesters. Included in Table 5 are the mean (and associated standard deviation) of misconception retainment for each topic, the Levene statistic *W*, the significance of the difference in variances p_V among groups, the F-ratio, the significance of the difference in means among groups, and the effect sizes as estimated by η^2 and ω^2. Note that the section labeled Three Planets combines all statements pertaining to Venus, Mars, and Saturn, in their respective sections of the inventory (refer to Appendix A). For the Spring 2013 and Fall 2013 semesters, respectively, $n = 126$, and $n = 110$. The range of all possible scores is from 1-3 for all tests.

With regard to the data for both the Spring 2013 and Fall 2013 semesters, Table 5 shows that there were generally no statistically significant differences in the ABI scores among the three forms, indicating that the order of statement presentation had no significant influence on student responses. Only on form #1 in the Spring 2013 semester did students report having a marginally higher degree of misconception endorsement than on forms #2 and #3 for that semester. Because we are using independent univariate tests, however, we do not see the *p* value of .022 to be significant in the context of the Bonferroni correction.

Effect of Fatigue

Students typically spend between one and one and a half hours responding to all 235 items (or 267 items in the case of the Fall 2009 semester), raising the question that student fatigue, at some point during the response process, may sacrifice the validity of responses provided by the students thereafter. If so, then responses to the ABI ought to become less meaningful in the later sections, and this can be tested, since the correlations between earlier and later items would be low. We used data from all of the original 235 statements in the inventories administered to the students in the Spring 2013 and Fall 2013 semesters. We calculated two mean misconception retainment scores: one for each of the first and second halves of the inventories (respectfully, 118 and 117 statements), as presented to the students. Since the three forms contain statements in essentially random orders, the scores on the first and second halves are expected to be well correlated, except if fatigue interferes with the response process. We also report the coefficient of determination (or r^2, where r is the correlation coefficient). The coefficient of determination gives a more meaningful interpretation of correlations between variables, because r^2 reports the total variation in one variable that can be explained (or accounted for) by variation in the other (Taylor, 1990). We further report the degrees of freedom, *df*, which is one less than the number of subjects, per semester. Individual scores range from 1-3 for all tests. For the Spring 2013 semester, where $n = 126$, we report summary statistics for the first half ($M = 1.88$, $SD = 0.26$) and the second half ($M = 1.95$, $SD = 0.26$). For the Fall 2013 semester, where $n = 110$, we analogously report summary statistics for the first half ($M = 1.87$, $SD = 0.25$) and the second half ($M = 1.96$, $SD = 0.26$). The correlations between the first and second halves are .772 ($r^2 = .59$, $df = 125$, $p < .0005$) for the Spring 2013 semester and .864 ($r^2 = .74$, $df = 109$, $p < .0005$) for the Fall 2013 semester. On the basis of this analysis, there is no evidence that students respond differently between the first and second halves of the inventory, which is consistent with the hypothesis that fatigue does not sacrifice the validity of the data.

As an additional check on the influence of fatigue (if any) on student responses to the inventory, we analyzed the internal consistency of the responses to select topics within the ABI. The internal consistency of a set of data is reported by coefficient alpha (α) (Schmitt, 1996), sometimes referred to as Cronbach's alpha. Coefficient α depends on the number of items in a test. Values of $\alpha \geq .70$ represent a group of items with "adequate" internal consistency. Using the original 235 statements, as administered to the students, we calculated α of the misconception retainment scores from the Spring 2013 and Fall 2013 semesters, separately for the Earth topic, with 37 statements, and the Sun topic, with 32 statements. Since the three formats contain statements in essentially random orders, the internal consistency in scores among the random orders should be essentially the same. For the Spring 2013 semester, we report summary statistics for the Earth topic ($n = 126$, $M = 1.92$, $SD = 0.27$) and the Sun topic ($n = 126$, $M = 2.00$, $SD = 0.27$); these are the same as in Table 5. In the Spring 2013 semester, values of α ranged from .79 to .84 for the Earth topic and .74 to .81 for the Sun topic. For the Fall 2013 semester, we report summary statistics for the Earth topic ($n = 110$, $M = 1.88$, $SD = 0.26$) and the Sun topic ($n = 110$, $M = 2.00$, $SD = 0.26$). In the Fall 2013 semester, α ranged from .83 to .84 for the Earth topic and .78 to .85 for the Sun topic.

We now briefly interpret the values of the coefficient α. While α may seem low given the large number of items per topic, the reader should be aware that statements within each topic of the ABI are associated with a particular factor structure that describes the inter-item correlations. In a forthcoming paper, we subdivide the statements within each topic into various groups determined using factor analysis, which establishes the groups based on highest inter-item correlations. The statements *within* each group exhibit high inter-item correlations; however, inter-item correlations between statements of *different* groups tend to be much lower. These results are consistent with α to be low for each topic as a whole, since not every item inter-correlates strongly with every other item in the topic. The same is true for all other topics in the ABI. Hence, the reader should not be alarmed by the somewhat low values of α. What is of importance here is that the response data have at least adequate internal consistency. It is thus unlikely that student fatigue would threaten the internal consistency of the inventory data.

Effect of False vs. True Statements

For each semester, we calculated the fraction of misconceptions endorsed even after instruction in the course. To score the data, we took the ABI statement responses, previously coded as degrees of misconception retainment as described in Table 4, and recoded the data into two categories, one for endorsing the incorrect belief even after instruction, and one for unlearning the incorrect belief anytime before the end of the course. Table 6 presents the mean fraction of incorrect beliefs endorsed even after instruction per semester, and the standard deviation of the mean fraction of incorrect beliefs endorsed.

Table 6

Mean Fraction of Incorrect Beliefs Endorsed Per Semester, Using All 215 Statements

Semester	Sample Size	Mean Fraction Believed	Std. Dev.	Format
Fall 2009	114	.200	.109	I
Fall 2010	107	.173	.109	I
Fall 2011	91	.186	.109	I
Fall 2012	91	.117	.097	I
Spring 2013	126	.275	.105	II
Fall 2013	110	.252	.101	II

Inspection of the data in Table 6 shows that the values for the Spring 2013 and Fall 2013 semesters, during which Format II was administered, are numerically higher than those of the first four semesters (Fall 2009 to Fall 2012), during which Format I was administered. An ANOVA test confirms that these differences are significant ($F(1, 637) = 110.4$, $p < .0005$, $\eta^2 = .148$, $\omega^2 = .146$), and that there is no violation in the assumption of homogeneity of variances ($W = 1.953$, $p_V = .163$). Hence, the format of the ABI may play a significant role on the overall reported degree of misconception endorsement.

As analyzed thus far, the large variability in the overall reported fraction of misconception endorsement may depend on the ABI format. It turns out, however, that by changing the format of the ABI, *correlations* between misconceptions remain relatively unaffected. In a paper in preparation, we will explicitly outline a method to assess these correlations. In particular, we will show that variability in the overall degree of misconception persistence has no significant influence on the correlations between misconceptions. By showing that the correlations are relatively unaffected, we can propose to group misconceptions together and sequence them in order of their *relative* difficulties, which can be used to produce orders to teach the associated concepts, from easiest to hardest, as defined by their respective mean misconception scores. These will be discussed in future papers as appropriate.

We then measured the effect of any bias from the way in which statements were phrased. To do this, we correlated the mean fraction of misconceptions endorsed in the Spring 2013 and Fall 2013 semesters by preparing two special statement sets: one for the 129 incorrect statements, and one for the 86 correct statements. That is to say, we correlated the fraction of "false" statements endorsed with the fraction of "true" statements rejected (we defined what we mean by "true" and "false" on page A-25). We found that the correlation between endorsement of false statements and the rejection of true statements is .373 ($r^2 = .14$, $df = 235$, $p < .0005$). This result is statistically significant, because $p < .0005$, and is consistent with the hypothesis that students who reject correct statements are also likely to endorse misconceptions.

While the correlation above measures the strength of the tendency for students to endorse an incorrect statement or reject a true statement, an additional test is necessary to discern whether or not students endorse incorrect statements more so than they reject correct statements. A test is needed, for example, to determine if students are more likely to endorse "Earth's axis is not tilted compared to the ecliptic" than they are likely to reject "Earth's axis is tilted compared to the ecliptic." We thus use a paired-samples *t*-test (Walker, 1985, pp. 320-323) to compare the mean difference in the fraction of false statements believed vs. fraction of true statements rejected. A paired-samples *t*-test on the data reveals that there is a statistically significant preference for students to endorse misconceptions more so than they reject a true statement ($df = 235$, $t = 5.77$, $p < .0005$). This result can be interpreted, for example, to mean that on a true-false-type questionnaire, students would be more likely to endorse the misconception that "Earth's axis is not tilted compared to the ecliptic" more so than they would reject the fact that "Earth's axis is tilted compared to the ecliptic." The paired-samples *t*-test illustrates that *there is a preference for students to endorse misconceptions more so than they reject scientifically-accurate statements*. This result is consistent with the notion that students who take an introductory-level course in astronomy have some tendency to believe what they hear, which suggests that *instructors should spend more time teaching in the context of common false beliefs, rather than simply focus on teaching fact by fact*. In the next section, we provide additional support for this suggestion by testing for differences in the fractions of misconceptions endorsed between the Spring 2013 and Fall 2013 semesters.

Effect of Teaching Pedagogy

Between the Spring 2013 and Fall 2013 semesters, two different teaching pedagogies were employed, as outlined in the Method section. To examine the influence of teaching pedagogy on the endorsement of incorrect statements or rejection of scientifically-accurate statements, we first performed an ANOVA test, using data from the 129 incorrect statements, by comparing the fraction of incorrect statements believed between the Spring 2013 and Fall 2013 semesters. We present summary statistics on the fraction of incorrect statements believed in the Spring 2013 semester ($n = 126$, $M = .302$, $SD = .136$) and the Fall 2013 semester ($n = 110$, $M = .264$, $SD = .140$). The variances in the mean fractions of misconceptions endorsed between the two semesters were not significantly different from each other ($W = 0.131$, $p_V = .717$). We found that the difference of incorrect statements believed between the Spring 2013 and Fall 2013 semesters is statistically significant ($F(1, 234) = 4.56$, $p = .034$, $\eta^2 = .019$, $\omega^2 = .015$). This result is consistent with the hypothesis that *addressing misconceptions is more effective in enabling students to reduce the number of misconceptions they endorse*. The implication is that one can get a student to confront their own misinformation more effectively by teaching why the misinformation is wrong. We note, however, that the effect size is small, in the sense described in the prior section. To be clear, the small effect size does *not* discourage instruction that addresses misconceptions in *small* classroom settings. Instead, the small effect size suggests that if a researcher was to administer the ABI in two small classroom settings, each with a different instructor and pedagogy, the researcher may not obtain a statistically significant result, because the sample size may not be large enough.

For our second ANOVA test, we used a separate data set consisting of the fraction of misconceptions endorsed, associated with 86 scientifically-accurate statements, between the Spring 2013 and Fall 2013 semesters. (Because both ANOVA tests use a different data set, they are independent of each other, so a MANOVA test is unnecessary.) We present summary statistics on the fraction of scientifically-accurate statements rejected in the Spring 2013 semester ($n = 126$, $M = .233$, $SD = .098$) and the Fall 2013 semester ($n = 110$, $M = .234$, $SD = .088$). The variances in the mean fractions of scientifically-accurate statements rejected between the two semesters were not significantly different from each other ($W = 2.127$, $p_V = .146$). We found that the difference in the fraction of endorsed misconceptions associated with scientifically-accurate statements is not at all statistically significant, i.e. $F(1, 234) = 0.001$, $p = .98$, $\eta^2 = .000$, $\omega^2 < 0$. This result indicates that there is no evidence to suggest that either teaching pedagogy is necessarily better than the other at helping students to learn the *correct* information. The implication is that from the standpoint of teaching strictly factual information, one does not need to spend extra time teaching in the context of misconceptions, but may simply present the information as usual.

Effect of Statement Wording

In the Fall 2009 to Fall 2011 semesters, students were encouraged to provide written feedback to the statements in the ABI which they thought were incorrect. The written feedback provides some quantitative assessment of the validity of the ABI as an instrument for assessing misconception endorsement. Namely, the feedback provides measures of:

1. the consistency between the misconception retainment codes (1, 2, 3) and the context of the written responses,
2. the consistency between the statement wording and its interpretation, and
3. whether or not the written feedback is an incorrect "correction" to the misconception.

For this analysis, we chose to look at responses in the Fall 2010 semester to the following five statements (in response to discussions with colleagues who study physics education, here at the University of Maine): sA68, "we do not have telescopes in space," sA172, "Saturn's rings are solid," sA189, "the Sun is the brightest star in universe," sA226, "the galaxies are randomly distributed," and sA263, "astronomical ideas of mass, distance, and temperature of planets are all speculative." From the written feedback, we determined, for each statement, "% Wrong Code," which is the percent of those *n* students whose written feedback is inconsistent with the response code (as determined by the bubble filled on the Scantron sheet), "% Misinterpreted," which is the percent of those *n* students whose written feedback indicates a misinterpretation of the statement itself, and "% Incorrect," which is the percent of those *n* students whose written feedback is an incorrect statement. An example of a wrong code is if a student endorses a misconception but indicates a retainment score of "1" or "2." An example of a misinterpreted statement would be if a student endorses that Saturn's rings are solid, but then writes "transparent." An example of incorrect feedback would be if a student rejects that the Sun is the brightest star in the universe, but then writes "Polaris is the brightest star." Table 7 presents an examination of written feedback to each of the five statements, where *n* is the number of students who provided written feedback.

Table 7

Examination of Written Feedback to Five Statements of the ABI

Statement	*n*	% Wrong Code	% Misinterpreted	% Incorrect
sA68	77	2.6	0.0	0.0
sA172	84	1.2	1.2	0.0
sA189	78	0.0	0.0	7.8
sA226	49	8.7	2.2	30.4
sA263	54	0.0	1.9	0.0

Table 7 shows that students mistakenly fill in an incorrect bubble between 0% and 9% of the time. Table 7 further shows that students misinterpret statements in the ABI only about 0% to 2% of the time. Hence, the frequency of either incorrect responses or statement misinterpretation at the end of the course is of relatively minor concern. It is worth clarifying that these results do *not* quantify the extent to which student recollections are consistent. A detailed analysis of recollection consistency will be presented in our next paper. Of the feedback that we had available to us, according to Table 7, we found that sA226, "the galaxies are randomly distributed," is the most likely statement of the group to be associated with incorrect response codes (8.7%) and incorrect "corrections" (30.4%). Many of the incorrect "corrections" mentioned that galaxies are evenly distributed on the sky. Given that sA226 has the fourth highest degree of misconception endorsement in the ABI, our results for sA226 tentatively suggest that students are less likely to provide an accurate statement correction to the very hardest items in the ABI, compared to easier items.

Discussion

We performed a series of tests on the validity of the data in the ABI. From our examination, we have determined the following:

1. The presentation order of statements in the ABI has no significant influence on students' self-reports.
2. The effect of fatigue in the process of completing the ABI has no significant influence on students' self-reports. Hence, the interested researcher need not concern oneself with the high number of ABI statements.
3. Students taking an introductory-level course in astronomy may be more likely to endorse a misconception than they are likely to reject a scientifically-accurate statement.
4. The change in the format of the ABI due to the rephrasing of about two-fifths of the statements may cause a significant increase in the overall reported fraction of misconceptions endorsed.
5. There is a statistically significant reduction in incorrect beliefs endorsed after instruction by teaching to students in the context of their misconceptions, instead of teaching using conventional fact-oriented lecture.
6. There are no significant issues with statement misinterpretation or incorrect response codes to the associated statements. However, there may be a higher tendency for students to provide incorrect feedback to only the very hardest items in the ABI.

From the standpoint of astronomy education, the ABI presents a lot of promise, in that it can directly probe misconceptions held by students and give meaningful insights as to the persistence of misconceptions. We have determined that the data in the ABI displays convergent validity, which further suggests that there is merit in using the ABI as a tool for studying misconceptions. In our next paper, we intend to show that the tendency for one's own recollection to be inconsistent is comparable to inconsistent responses on multiple-choice tests in a longitudinal context, which suggests that the ABI is of comparable validity to multiple-choice tests.

CONCLUSION

We have introduced a new instrument consisting of a comprehensive inventory of misconceptions held by college students taking an introductory-level course in astronomy. The instrument directly probes whether or not a student believes any of the misconceptions. We find that the instrument is *not* biased in terms of the order of statement presentation or its relatively long length. It would be instructive to see how teaching in the context of misconceptions held by the students improves their grades compared to more traditional teaching.

This concludes the first paper in our series. In future papers, we will examine the consistency of student recollections of their own past beliefs; present the theoretical background for principal components analysis, a technique for identifying groups of correlated misconceptions, as the technique applies to our overall project; clarify the extent to which semester-to-semester variability in misconception endorsement influences *correlations* between misconceptions, and we will address the concern that the correlations are not significantly affected by the per-semester variability in misconception endorsement. In subsequent papers in the series, we will also construct groups of topics from the misconceptions and propose an optimal sequence to teach concepts within individual topics in astronomy.

REFERENCES

Anderson, C. W., & Smith, E. L. (1988). *Children's conceptions of light and color: Understanding the role of unseen rays* (Tech. Rep. No. 166). East Lansing, MI: Michigan State University, College of Education, Institute for Research on Teaching, Res. Series.

Bailey, J. M., Prather, E. E., Johnson, B., & Slater, T. F. (2009). College students' preinstructional ideas about stars and star formation. *Astronomy Education Review*, *8*, 010110.

Becker, L. A. (1999). *Measures of Effect Size (Strength of Association).* Retrieved May 10, 2014, http://www.uccs.edu/lbecker/glm_effectsize.html .

Bland, J. M. & Altman, D. G. (1995). Multiple significance tests: The Bonferroni method. *British Medical Journal*, *310*(6973), 170.

Borkowski, J. (2014). *Tests for homogeneity of variance*. Retrieved January 25, 2014, http://www.math.montana.edu/~jobo/st541/sec2e.pdf .

Brewin, C. R., Andrews, B., & Gotlib, I. H. (1993). Psychopathology and early experience: A reappraisal of retrospective reports. *Psychological Bulletin*, *113*(1), pp. 82-98.

Clark, R. E., Kirschner, P. A., & Sweller, J. (2012). Putting students on the path to learning. *American Educator*, 6-11.

Cohen, J. (1998). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, N.J.: L. Elrbaum Associates.

Comins, N. F. (2001). *Heavenly errors: Misconceptions about the real nature of the universe*. New York: Columbia University Press.

Comins, N. F. (2014). *Heavenly errors*. Retrieved January 24, 2014, http://www.physics.umaine.edu/ncomins/ .

diSessa, A. A. (1982). Unlearning Aristotelian physics: A study of knowledge based learning. *Cognitive Science*, *6*, 37-75.

Flavell, J. H., Green, F. L., & Flavell, E. R. (1986). Development of knowledge about the appearance-reality distinction. *Monographs of the Society for Research in Child Development*, *51*(1), 1-87.

French, A., Macedo, M., Poulsen, J., Waterson, T. & Yu, A. (2008). *Multivariate Analysis of Variance (MANOVA).* Retrieved May 9, 2014, http://userwww.sfsu.edu/efc/classes/biol710/manova/MANOVAnewest.pdf .

Henry, B., Moffitt, T. E., Caspi, A., Langley, J., & Silva, P. A. (1994). On the 'remembrance of things past': A longitudinal evaluation of the retrospective method. *Psychological Assessment*, *6*, 92-101.

Hole, G. (2013). *Testing for homogeneity of variance with Hartley's F_{max} test*. Retrieved January 25, 2014, http://www.sussex.ac.uk/Users/grahamh/RM1web/ Testing%20for%20homogeneity%20of%20variance.pdf .

Kempton, W. (1987). Two theories of home heat control. In D. Holland & N. Quinn (Eds.), *Cultural models in language and thought* (pp. 222-242). Cambridge: Cambridge University Press.

Lombardi, D., Sinatra, G. M., and Nussbaum, E. M. (2013). Plausibility reappraisals and shifts in middle school students' climate change conceptions. *Learning and Instruction*, *27*, 50-62.

LoPresto, M. C., & Murrell, S. R. (2011). An astronomical misconceptions survey. *Journal of College Science Teaching*, *40*(5), 14-23.

Olson, J. M., & Cal, A. V. (1984). Source credibility, attitudes, and the recall of past behaviors. *European Journal of Social Psychology*, *14*, 203-210.

Posner, G. J., Strike, K. A., & Hewson, P. W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211-227.

Prather, E. E., & Brissenden, G. (2009). Clickers as data gathering tools and students: Attitudes, motivations, and beliefs on their use in this application. *Astronomy Education Review*, *8*, 010103.

Prather, E. E., Slater, T. F., Adams, J. P., Bailey, J. M., Jones, L. V., and Dostal, J A. (2004). Research on a lecture-tutorial approach to teaching introductory astronomy for non-science majors. *Astronomy Education Review*, *3*, 122-136.

Sadler, P. M. (1998). Psychometric models of student conceptions in science: Reconciling qualitative studies and distractor-driven assessment instruments. *Journal of Research in Science Teaching*, *35*(3), 265-296.

Sadler, P. M., Coyle, H., Miller, J. L., Cook-Smith, N., Dussault, M., & Gould, R. R. (2010). The Astronomy and Space Science Concept Inventory: Development and validation of assessment instruments aligned with the K-12 National Science Standards. *Astronomy Education Review*, *8*, 010111.

Schmitt, N. (1996). Uses and abuses of coefficient alpha. *Psychological Assessment*, 8(4), 350-353.

Taylor, R. (1990). Interpretation of the correlation coefficient: A basic review. *Journal of Diagnostic Medical Sonography*, *1*, 35-39.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction*, *4*, 45-69.

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the Earth: A study of conceptual change in childhood. *Cognitive Psychology*, *24*, 535-585.

Vosniadou, S., Vamvakoussi, X., & Skopeliti, I. (2008). The framework theory approach to the problem of conceptual change. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (pp. 3-34). New York: Routledge.

Walker, J. T. (1985). *Using statistics for psychological research: An introduction*. New York: CBS College Publishing.

Wallace, C. S., Prather, E. E., & Duncan, D. K. (2011). A study of general education astronomy students' understandings of cosmology. Part I. Development and validation of four conceptual cosmology surveys. *Astronomy Education Review*, *10*, 010106.

White, B. Y. (1982). Sources of difficulty in understanding Newtonian dynamics. *Cognitive Science*, *7*, 41-65.

Andrej Favia recently completed his Ph.D. at the University of Maine, Orono, ME. He is the communicating author and can be reached at mailto:Andrej.Favia@umit.maine.edu .

APPENDIX A

THE 215 STATEMENTS OF THE STUDY AND THEIR MEAN MISCONCEPTION RETAINMENT SCORE FROM FALL 2009 TO FALL 2013

		Stars:	
1	sA1	all of the stars were created at the same time	1.60
2	sA2	there are 12 zodiac constellations	2.13
3	sA3	all of the stars are about as far away from the Earth as the Moon	1.62
4	sA4	all stars are white	1.52
5	sA5	the constellations are only the stars we connect to make patterns	2.28
6	sA6	we are looking at stars as they are now	1.66
7	sA7	stars actually twinkle --- change brightness	2.02
8	sA8	the north star is the brightest star in the sky	2.03
9	sA9	stars have spokes	1.90
10	sA10	all stars have planets	1.80
11	sA11	stars last forever	1.48
12	sA12	the brighter a star is, the hotter it is	2.33
13	sA13	all stars are evenly distributed on the celestial sphere	1.89
14	sA14	all stars are the same distance from the Earth	1.45
15	sA15	all stars have same color and size	1.48
16	sA16	pulsars are pulsating stars	2.36
17	sA17	all stars are smaller than the Sun	1.62
18	sA18	the galaxy, solar system and universe are the same things	1.46
19	sA20	stars just existed --- they don't make energy or change size or color	1.65
20	sA21	all stars end up as white dwarves	2.04
21	sA22	all stars are stationary --- fixed on the celestial sphere	1.92
22	sA23	stars emit only one color of light	1.79
23	sA24	stars are closer to us than the Sun	1.69
24	sA25	there are exactly 12 constellations	1.70
25	sA27	all the stars in an asterism move together	2.40
26	sA28	a nova is the most powerful explosion	2.04
27	sA29	stars in the Milky Way are as close to each other as planets are to the Sun	1.89
28	sA30	stars run on fuel: gasoline or natural gas	1.84
29	sA31	“metals” have always existed in the universe	2.29
30	sA32	stars follow you in your car	1.44
31	sA33	we see the same constellations at night throughout the year	1.67
32	sA34	stars are fixed in space	1.72
33	sA35	stars in a binary system (two stars bound together by their gravity) would quickly collide	2.15
34	sA37	all stars are isolated from all other stars (none are binary)	1.92
		Solar System:	
35	sA40	the asteroid belt is an area like we see in star wars, very densely packed	2.08
36	sA41	Mercury is so named because there is much mercury on it	1.71
37	sA42	comet tails are burning --- because the comet is moving so fast	1.99
38	sA43	there is plant life on other planets in our solar system	1.72
39	sA44	Pluto is always farther from the Sun than is Neptune	2.10
40	sA45	a shooting star is actually a star whizzing across the universe or falling through the sky	1.80
41	sA46	Jovian planets (Jupiter, Saturn, Uranus, Neptune) have solid surfaces	1.85
42	sA47	the asteroid belt is between Earth and Mars	2.02
43	sA48	the Solar System is the whole universe or the whole galaxy	1.59
44	sA49	Jupiter is almost large and massive enough to be a star	2.18
45	sA50	all orbits around Sun are circular	1.71

46	sA51	planets revolve around the Earth	1.50
47	sA52	all planets orbit exactly in the plane of the ecliptic	2.02
48	sA53	Pluto is a large, jovian (Jupiter-like) planet	1.60
49	sA54	all constellations look like things they are named for	1.88
50	sA56	comets last forever	1.72
51	sA57	each planet has one moon	1.53
52	sA58	Mercury (closest planet to the Sun) is hot everywhere on its surface	2.03
53	sA59	the day on each planet is 24 hours long	1.54
54	sA60	all stars have prograde rotation (spin same way as the Earth)	1.74
55	sA62	there are no differences between meteors, meteorites, meteoroids	1.74
56	sA63	asteroids, meteoroids, comets are same	1.65
57	sA66	optical telescopes are the only “eyes” astronomers have on the universe	1.84
58	sA67	humans have never landed a spacecraft on another planet	1.70
59	sA68	we do not have telescopes in space	1.59
60	sA69	all planets have been known for hundreds of years	1.88
61	sA70	comets are molten rock hurtling through space at high speeds and their tails are jet wash <u>behind</u> them	2.05
62	sA72	there are many galaxies in a solar system	1.92
63	sA75	comets are solid, rocky debris	2.13
64	sA76	Jupiter's great red spot is a volcano erupting	1.85
		<u>Moon:</u>	
65	sA77	there is only one moon --- ours	1.34
66	sA78	the Moon doesn't cause part of the tides	1.55
67	sA79	we see all sides of the Moon each month	1.78
68	sA80	craters are volcanic in origin	1.92
69	sA83	the Moon is at a fixed distance from Earth	1.96
70	sA84	the Moon changes physical shape throughout its cycle of phases	1.63
71	sA85	the Moon doesn't rotate since we see only one side of it	1.83
72	sA87	the Moon has seas and oceans of water	1.64
73	sA88	the Moon is older than the Earth: a dead planet that used to be like Earth	1.80
74	sA89	the Moon is about the same temperature as the Earth	1.61
75	sA90	the Moon has a helium atmosphere	1.97
76	sA91	the Moon has an atmosphere like the Earth	1.65
77	sA92	the Moon has a smooth surface	1.57
78	sA93	the Moon sets during daylight hours and is not visible then	1.61
79	sA94	there is a real man in the Moon	1.38
80	sA96	because the Moon reflects sunlight, it has a mirror-like surface	2.00
81	sA97	the Moon will someday crash into Earth	1.91
82	sA98	the Moon is a captured asteroid	2.05
83	sA99	a lunar month is exactly 28 days long	2.47
84	sA100	at new Moon we are seeing the “far side” of the Moon	2.04
85	sA102	the Moon follows you in your car	1.42
86	sA103	the Moon is larger at the horizon than when it is overhead	2.23
87	sA104	the side of the moon we don't see is forever “dark”	2.04
88	sA105	the moon is lit by reflected “Earth light” (that is, sunlight scattered off the Earth toward the Moon)	2.01
		<u>Venus:</u>	
89	sA106	life as we know it can exist on Venus	1.75
90	sA107	clouds on Venus are composed of water, like clouds on earth	1.93
91	sA108	Venus is very different from earth in size	1.97
92	sA109	Venus is a lot like the earth in temperature	1.85
93	sA110	Venus is always the first star out at night	2.10

		<u>Earth:</u>	
94	sA111	Earth's axis is not tilted compared to the ecliptic	1.86
95	sA112	summer is warmer because we are closer to the sun during the summertime	2.01
96	sA113	once ozone is gone from the Earth's atmosphere, it will not be replaced	2.45
97	sA114	Earth and Venus have similar atmospheres	2.00
98	sA115	Earth is at the center of the universe	1.49
99	sA116	Earth is the biggest planet	1.44
100	sA118	Spring Tide is in the spring	2.31
101	sA122	X-rays can reach the ground	1.99
102	sA125	meteoroids Enter the atmosphere a few times a night	2.20
103	sA126	you can see a solar eclipse from anywhere on Earth that happens to be facing the Sun at that time	2.20
104	sA127	auroras are caused by sunlight reflecting off polar caps	2.21
105	sA128	the Moon is not involved with any eclipses	1.58
106	sA129	the day has always been 24 hours long	2.14
107	sA130	the air is a blue gas	1.64
108	sA131	Halley's comet will eventually hit Earth	2.17
109	sA133	the sun orbits the Earth	1.45
110	sA135	solar eclipses happen about once a century and are seen everywhere on Earth	1.97
111	sA137	only Earth among the planets and moons has gravity	1.69
112	sA141	seasons were chosen haphazardly	2.12
113	sA142	meteorites have stopped falling onto the Earth	1.79
114	sA143	the Earth will last forever	1.48
115	sA144	the Earth's magnetic poles go through its rotation poles	2.30
116	sA145	planes can fly in space	1.66
117	sA146	a day is exactly 24 hours long	1.89
118	sA147	a year is exactly 365 days long	1.74
119	sA148	seasons are caused by speeding up and slowing down of Earth's rotation	1.81
120	sA149	the Earth orbits the sun at a constant speed	2.38
121	sA150	the Earth is in the middle of the Milky Way galaxy	1.72
122	sA151	the sky is blue because it reflects sunlight off oceans and lakes	1.89
123	sA152	the Earth is the only planet with an atmosphere	1.61
124	sA153	comets affect the weather	2.00
125	sA154	the Earth is not changing internally	1.94
126	sA156	the tides are caused just by the Earth's rotation	1.70
127	sA157	Earth has a second moon that only comes around once in awhile --- “once in a blue moon”	1.64
128	sA158	the Sun is directly overhead everywhere on Earth at noon	1.84
129	sA159	tides are caused just by ocean winds	1.57
130	sA160	the Earth is flat	1.50
		<u>Mars:</u>	
131	sA161	Mars is green (from plant life)	1.62
132	sA164	Mars has running water on its surface now	1.78
133	sA165	Mars could be made inhabitable	2.29
134	sA166	Mars is the second largest planet	1.71
135	sA167	life, when it did exist on Mars, was quite advanced	1.68
136	sA168	there are Lowellian canals on Mars built by intelligent beings	1.73
137	sA169	Mars is Hot because it is red ... Mars --- god of fire	1.61
138	sA170	Mars is the sister planet to earth in physical properties and dimensions	2.22
		<u>Saturn:</u>	
139	sA171	Saturn is the only planet with rings	1.59
140	sA172	Saturn's rings are solid	1.67
141	sA174	Saturn's rings are caused by the planet spinning so fast	1.96
142	sA176	Saturn has only one ring	1.64

		Sun:	
143	sA177	the Sun is a specific type of astronomical body with its own properties. It is not a star	1.45
144	sA178	the Sun will burn forever	1.52
145	sA180	the Sun is the hottest thing in the galaxy	1.76
146	sA181	the Sun does not move through space	2.04
147	sA182	the Sun does not cause part of the tides	2.08
148	sA183	sunspots are hot spots on the Sun's surface	2.24
149	sA184	the Sun will blow up, become a black hole, and swallow the earth	1.98
150	sA185	the Sunspot cycle is 11 years long	2.54
151	sA186	the Sun's surface temperature is millions of degrees Fahrenheit	2.43
152	sA187	Sunspots are constant fixtures on the sun	1.97
153	sA188	the Sun is yellow	1.90
154	sA189	the Sun is the brightest star in universe	1.65
155	sA190	the Sun is the brightest object in the universe	1.77
156	sA191	the Sun always sets due west	2.44
157	sA192	the Sun is made of fire	1.47
158	sA193	the Sun is a “heat planet”	1.69
159	sA196	the Sun is the smallest star in universe	1.73
160	sA197	the Sun has no atmosphere	2.15
161	sA198	the Sun is the largest star	1.65
162	sA199	the Sun is hottest on its surface	2.02
163	sA200	the Sun has a solid core	2.16
164	sA201	the Sun has only a few percent of the mass in the solar system	2.21
165	sA202	the Sun is mostly iron	2.05
166	sA204	the Sun's surface is perfectly uniform	1.79
167	sA206	the entire Sun is molten lava	1.59
168	sA208	the Sun will explode as a nova	2.38
169	sA209	the Sun is hottest star	1.68
170	sA211	it is possible that the Sun could explode in the “near future”	1.92
171	sA213	the Sun doesn't rotate	1.93
172	sA214	the Sun is the only source of light in the galaxy --- Sunlight reflects off planets and stars so we can see them.	1.77
173	sA215	Sunspots are where meteors crash into the Sun	1.89
174	sA217	it is more dangerous to look at the Sun during an eclipse because the radiation level from sun is greater then, than when there is no eclipse	2.22
		Galaxies:	
175	sA218	the Milky Way is the only galaxy	1.43
176	sA219	the solar system is not in the Milky Way (or any other) galaxy	1.66
177	sA220	all galaxies are spiral	1.87
178	sA221	the Milky Way is the center of the universe	1.76
179	sA222	the Sun is at the center of the Milky Way galaxy	1.89
180	sA224	the Sun is at the center of the universe	1.63
181	sA225	there are only a few galaxies	1.72
182	sA226	the galaxies are randomly distributed	2.46
183	sA227	we see all the stars that are in the Milky Way	1.86
184	sA228	all galaxies are the same in size and shape	1.75
185	sA230	the Milky Way is just stars --- no gas and dust	1.73
186	sA231	new planets and stars don't form today	1.81
		Black Holes:	
187	sA232	black holes create themselves from nothing	1.89
188	sA233	black holes last forever	2.22
189	sA234	black holes really don't exist	1.76
190	sA235	black holes are empty space	2.01

191	sA237	black holes do not have mass	2.03
192	sA238	black holes are like huge vacuum cleaners, sucking things in	2.27
193	sA240	black holes are doors to other dimensions	1.79
194	sA242	black holes can be seen visually, like seeing a star or planet	2.05
195	sA243	we could live in a voyage through a black hole	1.71
196	sA244	we could travel through time in a black hole	1.82
197	sA245	black holes get bigger forever and nothing can stop them from doing so	2.08
198	sA246	black holes are actual holes in space	1.85
199	sA247	a single black hole will eventually suck in all the matter in the universe	1.89
		General Astrophysics:	
200	sA248	cosmic rays are light rays	2.28
201	sA252	astronomy and astrology are the same thing	1.62
202	sA253	gravity will eventually pull all the planets together	1.89
203	sA254	satellites need continuous rocket power to stay in orbit around the Earth	1.66
204	sA255	light travels infinitely fast	1.87
205	sA256	space is infinite	2.58
206	sA258	telescopes cannot see any details on any of the planets	1.80
207	sA259	gravity is the strongest force in the universe	2.33
208	sA261	we can hear sound in space	2.07
209	sA262	the universe as a whole is static (unchanging)	1.72
210	sA263	astronomical ideas of mass, distance, and temperature of planets are all speculative	2.37
211	sA267	there is a center to the universe	2.23
212	sA270	smaller telescopes enable astronomers to see smaller details	1.86
213	sA271	the most important function of a telescope is magnification	2.14
214	sA272	all space debris existing today is the result of planet collisions and explosions on planets	2.24
215	sA273	astronomers mostly work with telescopes	2.14

Planetary Biosphere Analogs with Extremophiles; Informal Science Education and Inquiry by Undergraduates Attending a Two-Year College

Pamela A. Maher and Camille Naaktgeboren

Exploring exoplanets *in situ* isn't feasible now, but that doesn't stop student interest in simulating it with extreme environment exploration on Earth.

Keywords: students - undergraduate-science majors - astrobiology - learning theory and science teaching - informal science education

There is a paucity of research involving students at the two-year college doing independent inquiry research coupled with Informal Science Education (ISE) presentation of findings to the general public. We undertook to fill this gap with students at a two-year college and a Nevada NASA Space Grant Consortium ISE Program course that related astronomy and extreme climate biology. The goals of this project were to design a stimulating science, technology, engineering and math experience outside of the formal classroom environment in the targeted field of astrobiology. Students participating in this project conducted library research to understand the nature and distribution of habitable environments in the universe. They determined the characteristics of potential habitable planets beyond the Solar System, and then drew analogs to these planets from their findings for culturing extremophiles found in the field.

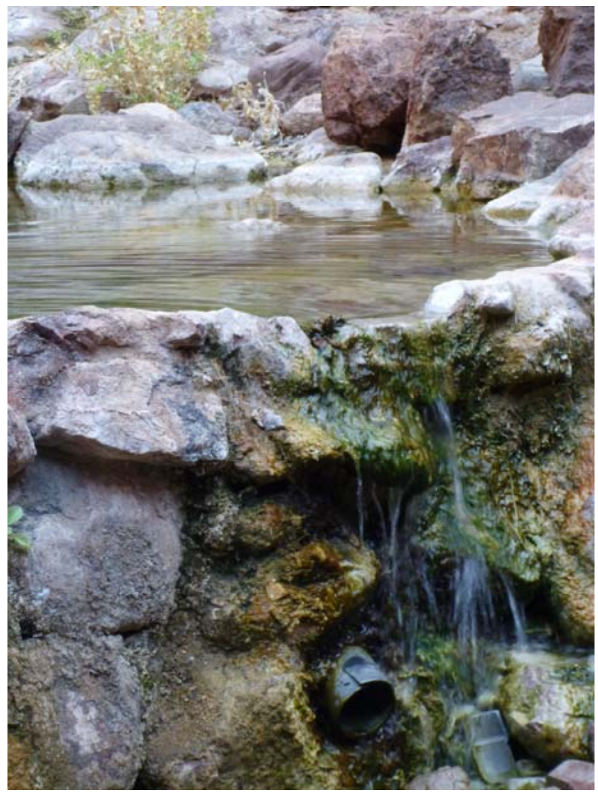


Figure 1. Pond 2, where biofilm samples were collected.

Twenty undergraduate students self-selected from a BIOL 251: General Microbiology class participated in the voluntary research. The project was outside of their regular course curriculum and was a free choice investigation. The purpose was to collect and study extremophiles (microbiological organisms that live in extreme conditions – in this case the ponds of hot springs, see Figure 1) and their potential relationship to life forms that could exist on planets within our solar system and on exoplanets. Collected samples were taken to the college's biology laboratory and cultured. This laboratory work took place on Saturdays and Sundays to allow the project to conform around the academic course lab schedule. The project time frame was one year in duration and consisted of two cohorts with 10 students in each cohort. At the end of each six-month cohort, students presented their research in a poster presentation during an astrobiology evening at the college planetarium.

Course Timeline

The general project timeline began with students first undertaking inquiry investigations to understand how life emerges from cosmic and planetary precursors. In the field and lab component' research they performed observational, experimental, and theoretical investigations to understand the general physical and chemical principles underlying the origins of life. Students also participated in free choice instructional sessions led by two of the college's Ph.D. microbiology professors. Instruction included PowerPoint lecture discussions and academic journal discussions as a basis for learning about extremophiles. Sessions focused on the evolutionary mechanisms and environmental limits, particularly some of the molecular, genetic, and biochemical mechanisms that control and limit evolution, metabolic diversity, and acclimatization of life. These would be used as a template for real world experiments, through the collection and culturing of extremophiles.

Figure 2. A biofilm in pond 2.

Finally, students were given presentation context and background skill help through NASA materials and resources, to help students become ISE educators. Students delivered knowledge to the general public on the recognition of signatures of life on other worlds and the early Earth, including identifying possible biosignatures which are usable to reveal and characterize past or present life in ancient samples from Earth, or extraterrestrial samples measured *in situ* or returned to Earth. A biomarker or biosignature is something that signifies that life was/is present. They can come in a few broad categories: a chemical compound that is produced by only living things, a type of visible-to-the-eye structure (see Figure 2), structures like stromatolites, or liquids with turbid conditions or colors not found in the rocks around it.

The project focused on providing an opportunity for ISE to take place on varied levels of inquiry depending on the background and course experience each student brought to the project. In this way the students were able to work in collaborative groups to collect and culture two types of extremophilic organisms. Participants collected halophiles and thermophiles in two permitted collection trips within an hour's drive from the college. Halophiles are found in the salt abundant areas around dry lakebeds. Thermophiles live in hot springs that occur naturally in the region and use of these was the ultimate tool for completing the research.

Student Findings

Samples showed growth characteristics of temperature-dependent extremophiles, with distinct growth curves (Figure 3). Optimum growth temperatures varied between samples but remained in the expected range of 40 to 50^{0}C. Data collected in experiments of the pond 2 samples (collection areas were identified by pond and number) were determined to be thermophiles. When these cultures were incubated at temperatures higher than the above maximum temperature, all but two cultures died and no further growth was established. (See Sidebar for lab procedures.) The two cultures that survived provide interesting possibilities for future research; although these two cultures did not grow when placed at temperatures higher than their maximum, the organisms in them survived and grew again when the cultures were incubated at the appropriate temperature. This indicates that there may be places both on Earth and on other planets where microbes are not actively growing but do exist and it

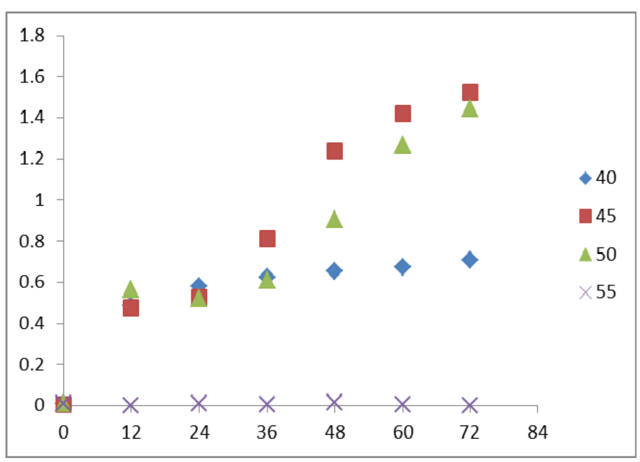


Figure 3. Growth curves of extremophile samples, absorbance at 550 nm versus hours.

would be worth sampling different regions that may appear to be void of life and attempting to grow any microbes that might be there under different conditions. This possibility further expands options for finding life in the universe.

Students also suggested additional studies to determine how these organisms exist in biofilms, as opposed to individual cultures. Biofilms are complex communities in which, sometimes, organisms will not grow without other organisms around them, or in which, sometimes, organisms take on very different characteristics than they normally have. Biofilms have relevance in not only identifying life on other planets but also understanding how it works on that planet. In our students' cases, they were detecting thermophiles by looking for its biomarker, formations indicating water flow, flexibility, and slimy or shiny appearances. These were identified, in our case, as the thermophile biofilms/mats that were seen when we were sampling.

Figure 4. A poster session for the college community.

Students served as conduits of ISE when they presented their material in poster form. The poster session was an open invitation to the college community and the general public to view student research and ask questions (Figure 4). During the poster presentation students demonstrated their emergent understandings by explaining how they did their background research, how they did sample collection in the field, and how they conducted their laboratory experiments. The student poster session exposed to the general public to the role of astrobiology in science.

This material is based upon work supported by the National Aeronautics and Space Administration under Grant/Contract/ Agreement No. NNX10AN23H, Nevada NASA Space Grant Consortium. Work was conducted under the auspices of the United States Department of the Interior, National Park Service, Lake Mead National Recreation Area. Study#: LAME-00210, Permit#: LAME-2012-SCI-0013. Pamela A. Maher is a doctoral student at the University of Nevada, Las Vegas studying science education. She works at the College of Southern Nevada Planetarium as the NASA Educator Resource Center Coordinator. She can be contacted at maherp@unlv.nevada.edu . Camille Naaktgeboren, Ph.D., is an instructor of microbiology at the College of Southern Nevada.

Received February 28, 2014; Accepted April 22, 2014.

The Lab Procedure

A project like this encourages interdisciplinary instruction, such as an astronomy course with biology department participation. Collection procedures (for those who wish to duplicate this) are described here. The student participants, with National Park Service collection permits, took water samples from some of the numerous hot springs found in the Las Vegas area. The collection area along Gold Strike Canyon trail in Lake Mead National Recreation Area was chosen for abundant saline formations and thermal springs.

Samples were inoculated onto M17 (Difco) media. Once inoculated the cultures were maintained at 45^0C in lighted conditions for 18 hours prior to being transferred into four different types of growth media. The growth media used included Nutrient Broth (NB), Lysogeny Broth (LB), Tryptic Soy Broth (TSB), and Lysogeny Broth; deMann, Rogosa, and Sharpe (LBMRS) growth medias. Their initial growth was established. All samples were transplanted to TSB growth media. Isolation of the organisms was performed with Chromagar orientation on plates. The isolated samples were placed in TSB media at fifty degrees Celsius (C).

Unique microorganisms were isolated and classified as individual samples. The ideal growth temperatures of these organisms were determined and these were maintained for an incubation period of 72 hours. Culture density was measured with a spectrometer (550 nm wavelength) to obtain growth curves. Broth culture incubates were streaked onto Tryptic Soy agar plates and incubated to determine whether the cells remained viable at 55^0 C. Staining was done and cell shapes and arrangements were examined at 100x power. Cultures were analyzed by means of a disc diffusion method. Each organism was grown in 15 mL of TSB for 48 hours and then filtered using a Nalgene filter unit with a 0.45 micron filter. The resulting fluid was used to soak Whatman antibiotic assay discs (2017). The discs were then placed onto bacterial lawns grown on TSA and incubated at 50^0C for 24 hours. The plates were then checked for zones of inhibition to determine whether there was antibiotic activity.

No, Dog, No! Assessing Moon Phase Misconceptions Using Children's Literature

Robert Swanson

Literature is abundant regarding misconceptions on Moon phases and children's books, but have you thought about using them to assess your college students?

Keywords: Teachers, undergraduate - non-science majors - Moon phases - misconceptions - children's literature - Astro 101

Others have examined representations of the Moon in children's literature (e.g. Trundle, Troland and Pritchard, 2008) and have made recommendations to educators on book usage. One of those is that children's books (either with correct or incorrect representations of Moon phases) can be used in inquiry-based activities in which students' regular observation of Moon phases can be brought to bear on the illustrations in the books. In this approach, students can compare and contrast their observational data with the book representations. Another suggested approach is for a teacher to carefully review books in advance and make sure that only scientifically accurate nonfiction books are used in Moon phase instruction. This is because a considerable number of children's books include misrepresentations of Moon phases. A third option offered is for an instructor is to pair a work of fiction with a scientifically accurate nonfiction book so that students can compare and contrast in order to resolve any misconceptions regarding the phases of the Moon,

You would not expect children's books to be anywhere near a college-level Introduction to Astronomy classroom textbook. However, I have found a way to make them work for me -- less as an instructional technique and more as an assessment tool. During instruction, I use scientifically accurate diagrams and simulations to teach about the Moon phases, occasionally throwing an inaccurate, but similar, diagram to make sure that students are catching on. My use of illustrations from children's books as an essay question on an exam is an attempt to challenge my students, probing to see whether they can extend their knowledge derived from science-book diagrams and simulations to an unexpected, less-scientific context.

From the Requests of Babes…

As a parent of three small boys, I spend a lot of time reading children's books, often the same ones over and over again. During a recent and unexpected break from school (snow days are rare in northeastern Mississippi), my youngest requested repeated readings of P.D. Eastman's *Go, Dog! Go* (1989). This book has been a favorite of all my boys and I can nearly recite the text from memory. Far from breeding contempt, this familiarity simply afforded me the chance to pay particular attention to the illustrations. As an astronomy instructor, two pictures in particular got my attention. In the first, a big group of dogs have piled into bed for a long night's sleep. A waxing crescent Moon is shown in the bedroom window. Since this phase is indeed visible in the evening sky, there is nothing wrong with this, as long as the window is facing toward the West. The very next page, however, has the dogs springing into action as the Sun rises in the very same window, with the accompanying text, "Get up! It is day. Time to get going. Go, dogs. Go!" In order for this to happen, the house would have had to execute a complete 180-degree turn in order to face East by morning. The only other explanation is that these dogs are very heavy sleepers and we are seeing the Sun in the western sky the following evening. Talk about letting sleeping dogs lie!

Since this snow day vacation fell during a time in which I was preparing the first test of the semester for my Introduction to Astronomy class, I immediately knew that I had just come up with an excellent essay question for my students. I enlisted my boys to rifle through the remaining books in the Swanson family library to find other illustrations of Moon phases. I marked the appropriate pages with sticky notes and brought the stack of books with me on test day. The instructions for the essay question were simple – select two of the children's books and describe what is right or wrong with the Moon phases and/or Sun position as presented.

…To the Minds of Students

By way of background, I teach the Moon phases using "The Cause of Moon Phases" and "Predicting Moon Phases" from the CAPER team's lecture-tutorials (Prather et al, 2008) as well as simulations (University of Nebraska-Lincoln's "Lunar Phase Simulator," http://astro.unl.edu/naap/lps/lps.html). I also have my students build lunar phase dials as designed by Kevin T. Denhe (2010) which they are allowed and encouraged to use on quizzes and tests. By the time the test rolls around, they should be quite familiar with the necessary orientation of Sun/Earth/Moon in order to produce the various Moon phases and their shapes. They also know the approximate times of moonrise/set and in which direction one would need to look in order to see a particular Moon phase. In short, coming into the test, they are equipped with all the knowledge necessary to critically examine the illustrations and text in children's books.

Even though they had not seen such illustrations during class, many were able to explain the inaccuracies on the exam. Some were even excited by the challenge. One particular student wrote:

> This activity even got me to stop and really think about it and changed my point of view on children books among other things. I would have never thought to look at that, but now I instantly look at my kids' books and wonder. It was thought-provoking, which is something schools these days need more of.

For those wishing to try this assessment activity in their classes, I provide here a list of other examples:

Yertle the Turtle (Seuss, 1986) – Moon phase is waning crescent, but text reads, "The Moon of the evening was starting to rise." Waning crescent Moon does not rise until the wee morning hours.

Kiss Goodnight (Hest, 2001) – Bedtime for the main character, Sam, should be in the evening, but the Moon phase shown is waning crescent (which, again, would only be visible in the early morning hours).

Harold and the Purple Crayon (Johnson, 1986) – Moon is impossibly always in the sky in almost the same position during his night's adventure.

The Going to Bed Book (Boynton, 1995) – Text says, "And when the Moon is on the rise," but the Moon phase pictured is the waxing crescent Moon, which is only easily visible just before it is about to set.

You're All My Favorites (McBratney, 2004) – Moon phase shifts abruptly from waxing crescent to waning crescent. While not impossible, it would require that the events of the book occur during a time span of several weeks. It would also require a change in the bedtime for the bears from evening (waxing crescent) to early morning (waning crescent).

Cowlick (Ditchfield 2007) – Viewing the rise location of the Moon (full moon) in comparison with the rise location of the Sun, it turns out that the illustrations are pretty much correct. The caveat (and challenge for the student) is to realize that the pictures are only correct during the winter months (declination of the Moon is positive while declination of Sun is negative).

REFERENCES

Boynton, S. (1995). *The Going to Bed Book.* New York, NY: Simon and Schuster.

Denhe, K.T. (2010). *Astronomical Observations: Laboratory Manual*. University Center, MI: Delta College. (Note that this lab manual is just published for use on campus - it is not a commercially available collection of astronomy lab activities. The Moon phase dial is actually included at the end of the lab manual.)

Ditchfield, C. (2007). *Cowlick.* New York, NY: Random House.

Eastman, P. (1989). *Go, Dog! Go*. New York, NY: Random House.

Hest, A. (2001). *Kiss Good Night*. Cambridge, MA: Candlewick Press.

Johnson, C. (1983). *Harold and the Purple Crayon*. New York, NY: HarperCollins.

McBratney, S. (2004). *You're All My Favorites*. Cambridge, MA: Candlewick Press.

Prather, E. E., Slater, T. F., Adams, J. P., Brissenden, G. (2008). *Lecture-Tutorials for Introductory Astronomy, 2nd Ed.* San Francisco: Pearson. The cited activities are "The Cause of Moon Phases" (pp. 79-81) and "Predicting Moon Phases" (pp. 83-85).

Seuss, Dr. (1986). *Yertle the Turtle and Other Stories*. New York, NY: Random House.

Trundle, K. C., Troland, T. H., and Pritchard, T. G. (2008). Representations of the Moon in Children's Literature: An Analysis of Written and Visual Text. *Journal of Elementary Science Education, 20*(1), 17-28.

Robert Swanson is a Physics and Astronomy instructor at Itawamba Community College, Fulton, MS. He can be reached at rsswanson@iccms.edu .

Received March 20, 2014; Accepted April 27, 2014.

Cover Thoughts - A Prior Knowledge Matrix

Lawrence Krumenaker

On this first *JRAEO* Issue cover, and here, are five celestial objects that are the first in a list, in some physical parameter or in some historical context. Identify them, and then rank them in the matrix by distance and size. Draw a line dividing these into solar system and stellar system zones.

Identities:

1. ____________________ 2. ______________________ 3. ____________________

4. ____________________ 5. __________________

	Smallest Size	→			Largest Size
Closest to Earth					
↓					
Farthest from Earth					

SOLUTIONS

Identities:

1. Halley's Comet and its Coma, 1986 – The first determined-to-be-periodic comet, formally 1P/Halley (Alternatively: its small nucleus). The distance to be used is where it is this year, 2014. (Note some will see the Milky Way here—a teachable moment in careful observation.)
2. Messier 1, a supernova remnant
3. Ceres – The first discovered asteroid, formally "1 Ceres"
4. NGC 1, a spiral galaxy (the galaxy at the top of the photo), first in the listings of the New General Catalog of objects
5. Sirius – The apparently brightest night time star (Alternatively: hidden in the glow, the first observed white dwarf star)

	Smallest Size				**Largest Size**
Closest to Earth	Ceres	(Ceres)			
	(Halley's Comet nucleus)	Halley's Comet coma			
			Sirius A (Sirius B)		
				Messier 1 (Messier 1)	
Farthest from Earth					NGC 1 (NGC 1)

We offer two alternative matrices. The one based one the obvious visible objects are listed in plain text. The alternative, using Halley's nucleus instead of its coma, and Sirius B, the white dwarf, instead of Sirius A, are shown in parentheses.

Using the first alternative, you can draw a dividing line between solar system and the rest of the universe by 'squaring off' the four upper left cells. With the other alternative you have three zones: the same upper four cells that are both in the solar system and solar system object sizes, the lower right four cells that are star size and distances or greater, and an overlap zone, Sirius B, which is beyond the solar system but Earth-sized.

The author has used matrices like these as a way to explore student prior knowledge, including whether the students understand what is in our solar system and what is not.

Photo credits: Halley's Comet, L. Krumenaker; Ceres, Hubble Space Telescope, NASA; Sirius and Messier 1, Chris Hetlage; NGC 1, Jay GaBany. All photos used with permission of the copyright holders.

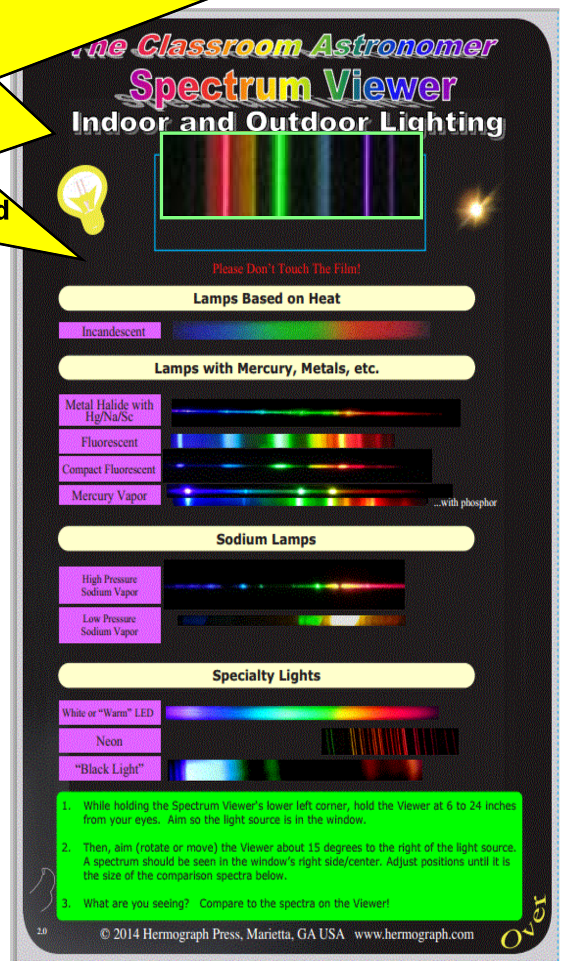
The Classroom Astronomer Spectrum Viewers

Two-sided viewers designed by an astronomy teacher for ease in seeing and identifying element and molecular spectra.

Introducing Indoor and Outdoor Lighting Viewer 2.0!

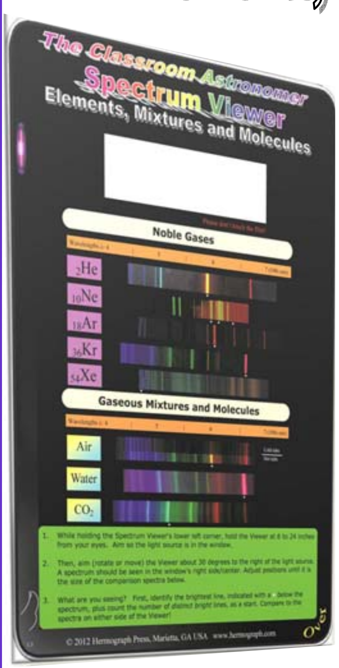
Improved!

Now with more realistic depictions of lighting spectra and better color renditions. Obverse side has additional light source data and updated equations for grading the cost– and energy-efficiencies of your neighborhood.



One of the biggest challenges that I have faced when using other spectrum viewers is that the students never know what they are supposed to see and struggle to hold their viewers at the correct angle to the light. The Spectrum Viewers alleviate both of these issues and provide a simple but effective classroom instruction tool. - NSTA *Science Teacher* review, November 2012.

Elements, Mixtures and Molecules



Easily examine gas tube spectra in physics, astronomy, and chemistry labs, with fifteen of the most common gas tubes' reference spectra.

After using these Viewers, students balked at using hand spectroscopes — Viewers were easier to use! **- Don Franklin, Mercer University, GA**

$9.50 each, Classroom Sets of 10: $85, 30: $228, 40: $285

Free Shipping on Orders over $100.

Web: www.hermograph.com/spectrumviewers

Instructions for Authors

The *Journal and Review of Astronomy Education and Outreach (JRAEO)* seeks to publish the highest quality articles that advance the understanding of astronomy teaching and learning and are likely to have a significant impact on the field of astronomy education and outreach. *JRAEO* welcomes manuscripts from authors around the world and from all theoretical frameworks and research methodologies.

Types of Manuscripts

You may submit a variety of materials for publication in *JRAEO*, provided they are not currently under consideration by other journals, nor previously published. Manuscripts can be in but not limited to any of the following type:

Research: All articles in *JRAEO's* Section A are peer-reviewable scholarly research. We accept quantitative, qualitative and mixed methods research articles. All undergo rigorous double-blind reviewing and are held to the same high standards for sample sizes, statistics, inference making and so on.

Articles should discuss the importance of the study to the field. A relationship between the study and previous work is generally needed. Methodology should be reported concisely.

All other articles are placed into *JRAEO*'s Section B. These include:

Commentary [Hypothesizing]: Invited or unsolicited 'white papers' on a topic of interest to the astronomy education, formal or informal, communities.

Ideas [In the Astronomy Education Universe]: These are items that may be of value to teachers or to those seeking research ideas, but are not necessarily peer-reviewable materials. Among these are ideas that have been tried out in classrooms as in-house experiments that could be more rigorously investigated later.

General features: Similar to those found in the editor's column [Field Observations] that take a more informal look at some item of interest to the community.

Other types of articles may be accepted.

While many articles have practical considerations for a teacher, *JRAEO* does not currently accept most practitioner articles, such as how-to-do or resource list stories. These may be submitted to a Hermograph sister publication, *The Classroom Astronomer* (www.classroom astronomer.com) .

Language

The language of the journal is English. We accept articles using both American and British English conventions. Articles from non-native English writers are also accepted, in English, though we request that all possible attempts to perfect the writing be done before it is submitted. We will do our best to make linguistic corrections unless doing so effectively and substantially rewrites the text. An additional abstract in the other language is welcome.

Formatting and Submission

Articles should be pre-formatted in APA style, in any version as far back as version 5. We have some "local" rules as well. The list of these is maintained on the *JRAEO* website but include such things as having two spaces after a full stop (a period, question mark, exclamation point, or colon), certain subheadings which can be bold, and a space follows a URL and then the period, etc.

Articles can be submitted at any time. The preferred way is via the File Uploader on the *JRAEO* website, but they can be emailed to JRAEO@toteachthestars.net. An Article Submission form, also found on the website, which contains contact information, preferred keywords, and other information, must be submitted at the same time.

Being an all-digital publication, there are no size limitations in terms of word count or page numbers. However, you have a better chance of a quicker acceptance if the author 'writes tight.' Superfluously worded articles may be sent back for rewriting even before the peer review process begins. Implications, backed by supporting evidence, are paramount.

Data tables should be easy to read and with all, and only, appropriate information. Color images (in graphs, graphics, or photographs) are welcome. All figures and tables should be sent in separate files though they may be also included in the text for help in final placement.

In addition to the instructions listed on the Information for Authors page, changes and current information can be found on the website at www.jraeo.com. If the first author is a subscriber, there are no fees to publish. Non-subscribers will have a $15 per 'printed' page fee. Being a subscriber is *not* to be construed as a right to be published. To avoid the page fee, *the first author* must be a subscriber *before* the article is submitted.

Review

All Section A articles are reviewed in an anonymous double-blind peer process by at least two reviewers. Some Section B pieces are reviewed double-blind by one reviewer. The editors often raise questions, and partially edit the submission both before and after the peer review process in order to improve the submission's quality and its chances for acceptance.

As a journal with a publication schedule, and thus, deadlines, we try to put accepted articles into the next issue, but this is not guaranteed. We also try to have articles reviewed and sent back to the author(s) within about 10 days from submission. Authors need to make corrections and return the revised manuscript in no more than a week to ten days after receiving the reviewers or editor's corrections. Late returns can mean a change in publication schedule of the article, or rejection of the article.

DR. LAWRENCE KRUMENAKER is the Editor of *JRAEO*. Dr. Krumenaker has deep roots in the astronomy education community, having been an astronomy and physics instructor since the 1980s at various universities and colleges. His Ph.D. was in science education from the University of Georgia. The 2008 dissertation was entitled "The Status and Makeup of the Modern U.S. High School Astronomy Course in the Era of No Child Left Behind," which generated three articles in *Astronomy Education Review*, and others in *The Science Educator* and *The Planetarian*. His current research involves astronomy education in other countries.

Krumenaker has worked in journalism since the late 1980s, having started at ABC's *20/20* show as a researcher of science stories. He has been published in numerous astronomy, science, and computer magazines, and is currently the publisher and editor of *The Classroom Astronomer* magazine. Krumenaker is a member of the National Association of Science Writers and the International Science Writers Association. As an astronomer, he does stellar spectroscopy, from time to time, of cool and emission-line stars. One of his key research results was the discovery of the Milky Way's only microquasar, SS433.

DR. KRISTINE LARSEN is the Assistant Editor of *JRAEO*. Astronomy education and outreach have been the central focus of her decades-long career, beginning in 1981 when, as a college freshman at Central Connecticut State University, she began working as a planetarium lecturer and observatory assistant. While completing a Ph.D. in Theoretical Physics at the University of Connecticut, she returned to her alma mater as a faculty member in 1989, where she currently holds the rank of Professor in the Physics and Earth Science Department and serves as Faculty Coordinator of the Copernican Observatory and Planetarium. She teaches courses in introductory astronomy, observational astronomy, and astrophysics, as well as courses for pre-service teachers and interdisciplinary courses for both the University Honors Program and First Year Experience Program.

Larsen's scholarly work focuses on the intersections of science and society, especially science pedagogy and outreach, the history of women in science, misconceptions of science, and depictions of science in literature and film.

Journal and Review of Astronomy Education and Outreach

May 2014 Issue 1
Volume 1 Number 1

Section A – Research

Section B – General Articles

Hermograph Press LLC, Marietta, GA 30066 USA
 www.jraeo.com