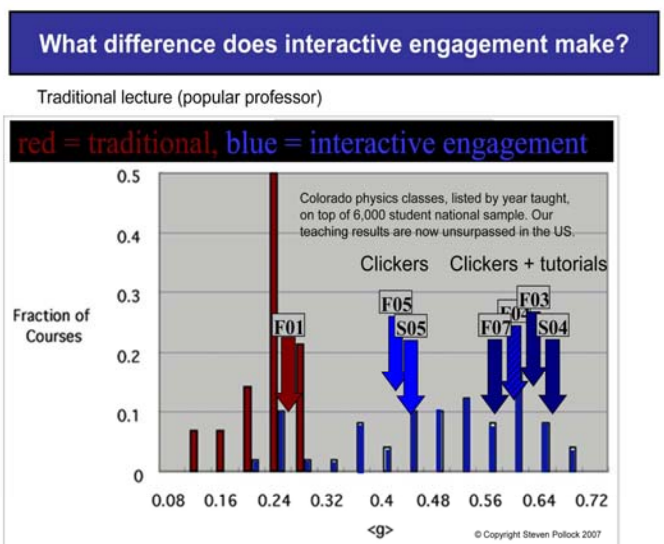
Developing a Research Base for Effective Teaching Using Fiske Planetarium

Seth Hornstein, Doug Duncan, and Briana Ingermann

A. Project Overview and background

Approximately 3,000 CU students take introductory astronomy classes each year, primarily through ASTR 1000, 1010, 1020 and 1200. CU spent over $2M to modernize Fiske Planetarium into a digital video theater that allows data and animations to be shown in beautiful high resolution. Faculty expect that many topics from all these APS classes can be more productively taught in a planetarium where time, geometry, and motion can be easily simulated and varied. However, we don't have data to test these expectations, and we do have some reason to worry. Studies by the CU Physics Education Research group demonstrate that our faculty are not different from those elsewhere, that even the best lecturer only gets students to achieve about 30% mastery of all the material taught in a semester if the teaching approach is pure lecture. Mazur at Harvard (2011) finds that demonstrations usually do not improve learning at all, and sometimes reduce it. How do we know that a lecture in the beautiful Fiske environment enhances students learning, and is not a fancy version of demos that do not help learning? We need, and propose to gather, essential basic data to find out. This is important enough that Fiske planetarium will donate time and money to the project (see budget section).



The graph shows the fraction of *everything taught* students learn *thoroughly* during the semester. Red and blue histogram bars are for 52 classes throughout the US.

Between 65% - 85% of students rate their time spent at the planetarium highly or extremely highly on FCQs, and faculty report that there is overwhelming support for more time at Fiske. While this implies a positive influence on student engagement and affective viewpoints on science, we do not currently have other data to support this these affective gains.

Knowing the importance of active learning, some faculty use Fiske in a more active way, with clickers, students discussions, even some lab work "under the stars." Again, we don't have data to show the effectiveness.

We propose to investigate the effectiveness of different teaching methods on student learning gains, engagement, and attitudes in the digital planetarium environment. We have significant faculty support for doing these trials through a series of controlled experiments that gathers rigorous assessment data. If, as we hypothesize, more active and student-centered approaches produce higher learning when used in the planetarium, we will leverage those results to support increasing faculty involvement in active-engagement learning methods in both the planetarium and regular classrooms.

Our goals with this study are as follows:

1. To determine the effectiveness of different methods of teaching in the planetarium environment (including a method new to APS classes: case studies) in contrast with a classroom environment
2. To deepen expertise and promote the use of interactive teaching and effective teaching environments amongst APS faculty

Using work supported by a previous ASSETT grant, we determined that introductory students generally perform poorly on exams regarding the common topic of 'sky motions'. This is a difficult concept since it involves visualizing the Sun-Earth relationship from an external point of view and translating that arrangement to a personal sky view perspective. That translation is a skill that is not inherent in many disciplines. From interviews with faculty and evaluation of 4-5 years of past exams we are confident that this topic will provide an excellent opportunity to test student outcomes from various ways of teaching in the dome vs lecture in the classroom. We have agreement from the instructors of three courses to test different ways sky motions can be taught. All three have agreed to administer a selection of the same exam questions, and we will run additional assessment with surveys and student interviews.

B. Background & Theoretical Framework

In the past few decades a small number of studies have been carried out to analyze learning in a planetarium environment. Initially, the results of these studies were largely inconclusive, with several determining that the planetarium is more effective, several concluding that there is no difference, and a few finding that the classroom is a more effective learning environment than the planetarium (Yu, 2005 and references therein). However, these studies all took place prior to the digital age in planetariums when only the motions of the night sky could be displayed.

A rapidly-increasing number planetariums now have digital capabilities. Over 1000 such planetariums operate in the US (Loch Ness Productions, 2015). With these upgrades, planetariums are becoming much more able to demonstrate different concepts in addition to night sky motions. Digital theaters allow for an immersive experience that can illustrate physical phenomena from multiple perspectives (e.g., Moon phases from a viewpoint on Earth's surface compared to a viewpoint from above the Earth-Moon system), demonstrate physical changes over time, simulate complex astronomical phenomena, and display research-based data sets. Although results from a decade ago seemed inconclusive, contemporary research using immersive domes (supported by multimedia and cognitive theory) suggests more strongly that the digital planetarium environment may lead to higher learning gains than other environments such as the classroom or flat-screen simulations.

Sumners et al. (2008) found that 221 students from grades 3-12 demonstrated statistically significant learning gains in understanding basic Earth science concepts after watching a 22-minute full-dome show. Their study also indicates that students exposed to interactivity (through discussion or associated hands-on experience) learned more than those just seeing or hearing the show. Chastenay (2016) investigated how five of six students (ages 14-16) learned effectively from a planetarium program developed to demonstrate Earth-based and space-based perspectives of lunar phases. Yu et al. (2015) find evidence that undergraduate students can learn a spatially complex topic such as "seasons" more effectively using visualizations presented in a full-dome planetarium environment than in non-immersive (flat) formats.

Results from Gillette (2014) suggest that planetarium programs can have a negative effect on learning if extraneous visuals are displayed, causing distraction. This is an important reminder based on multimedia theory that we must be aware of cognitive overload when trying to communicate specific content learning goals in the immersive theater. Careful assessment is therefore a critical tool for developing programs and teaching methods that lead to positive learning gains.

Few of the studies mentioned have been conducted with undergraduate students. Furthermore, no investigations have been carried out to formally analyze methods of interactive teaching using the dome. The use of iClickers in combination with peer discussions (e.g. Think-Pair-Share or Peer Instruction) have been shown to strongly increase learning in the classroom environment (e.g., Mazur, 1997; Duncan, 2006; Keller et al., 2009), but no studies have analyzed the use of these methods in the planetarium. Interactive learning through "case studies" has been a very successful method of teaching in the medical, law, and business fields for decades and have since expanded into the sciences (Herreid, 1994; NSF, 2016). However, it also has not been examined as a method of interactive teaching in the planetarium.

C. Study Design and Methods

We have already begun some testing of these concepts. In spring 2016 we are carrying out a small, informal study testing the concepts presented in this proposal. Although we do not have a complete set of data in hand at the time of this submission, analysis of this data will inform our study.

In order to test the topic of 'sky motions,' the project team has settled on three important sub-topics: How does the appearance of the sky change with latitude, longitude, and time (season of the year)? We plan to test and assess three different methods of instruction with three different introductory classes:

1. Class visits Fiske, sky presented with traditional lecturing (e.g. "This is how the sky looks from Boulder. This is how the sky looks from the equator…").
2. Class visits Fiske, sky presentation includes interactive Think-Pair-Share questions.
3. Same as Class 2, but students return to Fiske for an additional lab session which is run as a *case study.* Briefly, students, working in small groups, will be told that they are on the show "Survivor" and have been dropped at a random location on Earth. They will be asked to determine their latitude, longitude, and the time of year. Methods will be entirely up to the students. The planetarium operator will respond to request such as, "Show us sunrise and sunset today, please." A <u>prototype test</u> of this was conducted in early 2016. Students were very enthusiastic, saying that although it was more challenging, it was "much better than a traditional lab."

Methods 1-2 are currently commonly used by various instructors. In addition to assessing the effectiveness of these current methods, we've introduced method 3, which tests a new course transformation component (a "case study" format). We are not testing the most traditional sense of a classroom (one that does not employ any active-learning techniques) because a plethora of published research studies already demonstrate that active-learning methods consistently lead to higher learning gains than traditional classrooms. Furthermore, almost all APS instructors of introductory astronomy courses already utilize at least one method of active-learning.

Assessment will be coordinated and administered by Ingermann with input from the PI and Co-I in the form of pre- and post-instruction surveys, one-on-one interviews, and Think-Pair-Share questions (for methods 2-3). A selection of similar exam questions will be given in all three classes. Emphasis will be placed on assessing student learning gains, but a smaller subset of survey and interview questions along with observation of students during class time will provide some evidence of student engagement and affective values, as we expect the planetarium environment to be influential in such regards.

Presently, several infrastructure components can also be leveraged to help in this study. Astr 1010 already has supporting TAs and LAs for lab sections, who will be able to aid in the test of the case study (method #3). Fiske Planetarium also owns a set of iClickers available to use for large incoming classes, thus lowering the barrier for entry when teaching interactively in the dome.

If the method of the case study is successful, the existing infrastructure of TAs and LAs in many large astronomy classes may also be used to hold 'office hour' sessions in the dome for classes that do not have a lab component.

D. Timeline

Spring 2016: complete brief, informal study (nearing completion)
Summer 2016: data analysis of informal testing from spring 2016, apply for IRB approval, develop assessment questions and interviews instructed by the informal study
Fall 2016: data acquisition with available 1000, 1010, and 1200 classes
Spring 2017: data acquisition with available 1000, 1010, and 1200 classes
Summer 2017: data analysis and summary of results

E. Outcomes & Impacts

Fiske is uniquely positioned as a planetarium because it benefits from CU's excellence in science education research and because, through leadership among planetariums, many theaters look to Fiske for advice. The results of this study have the potential to impact hundreds to thousands of students at the departmental, inter-departmental, and national levels.

Departmental Impact and Sustainability
In addition to contributing to the sparse research base on planetariums as a university teaching environment, we also plan to utilize this project to emphasize the importance of learner-centered teaching to the APS department. In order to make changes to these courses sustainable, our major focus will be on lowering the barriers of entry for teaching in the planetarium using active-learning methods. The way we plan to do this includes:

1. *Pre-identify instructing faculty*: In the APS department, faculty teaching requests are prompted a year in advance. This allows us to identify the faculty responsible for teaching the ASTR 1000, 1010, and 1200 courses early and discuss how we can support their teaching using the planetarium. Both new and experienced instructors can then be shown updated (evidence-based) teaching methods and how the planetarium can aid in their teaching. This also allows us to

request to populate these courses with instructors who would help sustain these course changes in the first few years, aiding in the momentum of the course changes.

2. *Make time-saving handouts for faculty*: We will produce a set of 1-page handouts available for all APS faculty as guides for teaching different topics in the theater. Faculty don't sit in on each other's classes but Fiske staff see all and this project will help us incorporate the most successful approaches into handouts given to all faculty who plan to bring their classes to Fiske.
3. *Incorporate case study approach into existing lab manual*: The APS department maintains a *recommended/default* lab manual given to each instructor. PI Hornstein is the Education Director of Sommers Bausch Observatory, and maintains the manual, so he has the authority to establish the case study activity as a default lab in the course (provided the data show it to be effective).
4. *Leverage Fiske's iClicker set*: Instructors who do not otherwise use clickers as a teaching tool may use Fiske's full set of clickers when their classes visit. Corresponding sets of clicker questions for different subjects are also available. Faculty who use the theater will be encouraged to engage in interactive teaching and utilize the available tools, should this study demonstrate its effectiveness.

Since we will be relying on the TAs to help instruct the case study sessions, we plan to run a short session for TAs on how to lead a case study. If the case study model proves effective, we would extend this training into the departmental TA training session that occurs before the start of each fall semester. With trained TAs, we could expand the case study model into large classes that do not have associated lab sections by hosting sign-up planetarium sessions or "office hours under the stars" outside of class.

Introductory astronomy is taught by a rotation of ~10 faculty and graduate students, so these methods have the potential to involve many faculty members within APS. Informed by the results of this study, the most effective use of the planetarium will be also be reported and promoted during faculty meetings.

Inter-Departmental Impact

Fiske is currently involving an increasing number of faculty members and departments outside of its host department, APS. Since the planetarium has the capability to visually demonstrate concepts in a variety of subject areas, including aerospace, biology, chemistry, and the arts, the results of more active-learning approaches in the planetarium may be used to inform other interested departments on the process of developing effective learning tools at Fiske. Based upon the results of our study, we may be able to provide an increasingly effective learning environment for many different campus departments.

National Impact

More broadly speaking, the topic of 'sky motions' to be targeted in this study is a widely taught set of concepts in introductory astronomy classes all across the nation. Nearly 240 national universities host a planetarium capable of replicating similar teaching techniques, yet very few published studies come out of planetariums. Publication of this study could therefore lead to more effective instructional use of planetariums by many other universities across the nation.

F. References

Chastenay, P. 2016. “From Geocentrism to Allocentrism: Teaching the Phases of the Moon in a Digital Full-Dome Planetarium.” *Research in Science Education*, 46 (1): 43-77.

Duncan, D. 2006. “Clickers: A New Teaching Aid with Exceptional Promise.” *Astronomy Education Review*, 5: 70-88.

Gillette, S. (2014). “The Effects of Seductive Details in an Inflatable Planetarium.” *Planetarian*, 43 (2): 26-28, 30.

Herreid, C.F. 1994. “Case Studies in Science - A Novel Method of Science Education.” *Journal of College Science Teaching*, 23 (4): 221-229.

Keller, C., Finkelstein, N., Perkins, K., Pollock, S., Turpen, C., & Dubson, M. 2007. “Research-Based Practices for Effective Clicker Use.” *AIP Conference Proceedings*, 951, 128.

Loch Ness Productions. 2015. Fulldome Theater Compendium. http://www.lochnessproductions.com/lfco/lfco.html, accessed 13 April 2016.

Mazur, E. *Peer Instruction: A User’s Manual*. Prentice Hall, 1997.

NSF National Center for Case Study Teaching in Science. 2016. http://sciencecases.lib.buffalo.edu/cs/about/, accessed 14 April 2016.

Sumners, C., Reiff, P., & Weber, W. 2008. “Learning in an Immersive Digital Theater.” *Advances in Space Research*, 42: 1848-1854.

Yu, K.C. 2005. “Digital Full-Domes: The Future of Virtual Astronomy Education.” *Planetarian*, 34 (3): 6-11.

Yu, K.C., Sahami, K., Sahami, V., & Sessions, L.C. 2015. “Using a Digital Planetarium for Teaching Seasons to Undergraduates.” *Journal of Astronomy & Earth Sciences Education*, 2.

G. Budget Justification

Our budget is based on the preliminary work we did getting faculty members to commit to the project and trying out the “case study” approach with a trial group of 16 students. Note that Fiske Planetarium will match Briana Ingermann’s salary with an equal amount if we are funded.

H. **Budget** $9400 - Total Requested Budget

$3800 (1 month, 0.5 FTE) for PI Senior Instructor Hornstein - Hornstein will coordinate the effort, lead assessment development and ensure project makes adequate progress

4500$ (1 month, 100% time, distributed over the academic year) for Research Assistant Ingermann - Ingermann will lead the data analysis and documentation portion of the effort. The budget will provide ~230 hours of Ingermann’s time. It will be matched by assigning ~230 hours of Ingermann’s Fiske responsibilities to this project. As a part-time staff member of Fiske Planetarium (and with a Master’s thesis in education research), Ingermann is well suited for these aspects of the program and has adequate time in her work schedule to accommodate the workload.

$1100 for undergraduate assistant hourly time for data processing (Scantron forms, open ended question grading (with oversight), etc.) This will provide ~100 hours of undergrad time