Where's the data? Why, here it is!

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Abstract

The interest in astronomy education research is growing, and has transformed over the past decade (or basically since the turn of the century) to include more qualitative studies. The questions being asked have gone from "is the planetarium an effective teaching tool" to "why is the planetarium an effective teaching tool." In addition, a move to include grey literature as acceptable research sources has opened up a way for planetarians who are not astronomy education researchers to share their observations and insights. We planetarians need to take advantage of this open door and pro-actively contribute to the field.

Introduction

Nearly 10 years ago I gave a paper at the Great Lakes Planetarium Association conference (2010, Notre Dame) in which I asked "Where's the Data? (The need to survey planetariums for educational efficacy)." I reviewed recent publications on planetarium efficacy and mourned its scarcity. The paper wasn't attended by many, and was duly included in the conference proceedings,[1] where it also wasn't noticed and became just another unfindable piece of grey literature.[2]

I am happy to revisit this question in 2019 with the observation that astronomy education research has come of age in the past decade and the question of "are planetariums effective" is being answered as "yes." Moreover, the adoption of fulldome and its immersive ability have changed the question, from "are planetariums effective" to "why are planetariums effective," opening new lines of research.

This is wonderful news, but for planetarians who have worked "in the trenches," so to speak, for years, there is something even better: our intuitions are being validated. Many veteran planetarians, myself included, have shared thoughts and observations over the years with each other about how and why a planetarium is an effective teaching tool, and our unquantifiable gut intuitions are right. Planetariums are the best tool to teach:

- Movement over time, such as daily motion, celestial motion, and other periodic motions that cannot be easily observed;
- Concepts that require or benefit from spatial and three-dimensional understanding, such as the sun-earth-moon system, moon phases, and seasons; and
- Concepts that benefit from allocentric and geocentric observation, again such as moon phases and seasons, and a sense of scale, distance, and time.

In addition, we planetarians have known in our hearts that our facilities—both fixed dome and portable—make an impact on the affective realm of student experience and that positive experiences can improve learning; that teachers need to be active participants to make the best use of the planetarium experience; and that the dome is just one tool that can be used to educate and cannot be expected to "teach everything my students need to know to pass the test in 45 minutes."

So what happened?

Several major changes in educational research, along with planetarium technology change and the much-needed debut of a research database, have taken place roughly since the turn of the decade. In his 2017 paper "Illuminating Learning in the Dome: Constructing the International Studies of Astronomy Education Research Database,"[3] Dr. Timothy Slater at the University of Wyoming provides an overview of the new iSTAR Database (more on this below). He also reviews discoveries in his 2017 book *Research on Teaching Astronomy in the Planetarium*, co-written with Coty B. Tatge.[4] Among his findings is the existence of a research gap in astronomy education, roughly from 1990 to 2005. This also is the approximate time frame of the adoption of digital fulldome by many planetariums, a technology change that transformed planetariums from "theater of the stars" to immersive learning environments. Although beloved analog projectors (many still in use because of their superior star quality) had always provided an immersive environment, the ability to move more than just the stars opened the dome to clearer explanations of daily motion, the seasons, and other non-observable concepts. Taken together, this divided astronomy research into two eras: the analog era and the digital era.

Research following the digital evolution also benefited from what he calls "paradigm wars,"[5] a time roughly between 1980 and 2000 that saw less insistence on quantitative studies and the acceptance of qualitative and mixed methods research, especially in astronomy education research.

Slater also has championed the use of grey literature while conducting research in astronomy, arguing that theses and dissertations undergo as much, if not more, review as papers appearing in refereed journals. In "Undiscovered Value of Grey Astronomy Education Research Results,"[6] Slater notes that "Grey literature is the scholarly work that has

This paper is intended to be a companion to the IPS White Paper titled "The Value of Education in the Planetarium" written by Jeanne Bishop.

1 Shanks, Sharon. "Where's the Data? The Need to Survey Planetariums for Educational Efficacy," *Proceeding of the Great Lakes Planetarium Association*, October 20-23, 2010, Notre Dame University, pp 68-70.

2 Grey Literature: "That which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers." www.greylit.org/about

3 Slater, Timothy F. "Illuminating Learning in the Dome: Constructing the international Studies of Astronomy education Research Data Base." *Planetarian*, 56 (4), December 2017, p 11.

4 Slater, Timothy F. and Tatge, Coty B. (2017) *Research on Teaching Astronomy in the Planetarium.* Springer Briefs in Astronomy. ISBN 978-3-319-57200-0

5 ibid, p 15

66 Slater, Timothy F. (2016) "Undiscovered value of grey astronomy education research results." *The Grey Journal,* 12 (3).

been done and presented at conferences or exhaustively written up in dissertations, but never formally published in refereed journals." He provided an example of the best-known example of grey literature: Philip Sadler's *A Private Universe*.[7]

"Many authors publishing reviews of research rarely include graduate theses and dissertations, despite the fact that most have been more thoroughly reviewed by a larger number of scholars—those four, five, or six scholars who sit on graduate review committees—than those two or three who review manuscripts for journals."[8]

Other changes Slater points out include a switch from live presentations by an astronomy educator with the analog projector to pre-recorded programs,[9] and a change of focus from star and constellation identification to cutting-edge research and explaining high-interest concepts (black holes, for example). Other factors impacting change: the slowdown in the US economy starting in 2008, the push to adopt national education standards, and growing diversity among students.

Some notable conclusions from *Research on Teaching Astronomy in the Planetarium*:

"Taken together, there are tremendous forces shaping the way planetariums serve as a critical component of the larger US education portfolio. As a result, the future research questions pursued by planetarium education researchers will evolve as well." (page 25)

"Moreover, planetarium education researchers will have to engage in shedding the one-size fits all education approach and find innovative ways to individualize the planetarium learning experience." (page 25)

"What we now have come to better appreciate is that the planetarium in and of itself in isolation is not a magical silver-bullet for solving all of astronomy education's challenges for improving learning and attitudes. Instead, planetarium education programs need to use the same educational theory-driven, research-confirmed best practices in science education to help enhance learners' cognition and affect. The planetarium is unarguably able to capture attendees' innate interest, but planetarium education research confirms that lasting change requires purposeful educational decisions in order to be relevant and effective." (page 123)

What do researchers need?

In "A Community Discussion about Sharing and Publishing Space Science Education Research and Evaluation,"[10] Buxner et al reported that a Special Interest Group at the Astronomical Society of the Pacific's 2011 annual meeting expressed several specific concerns, including

1. The lack of a central place to publish and to read studies specifically in space science education.
2. The increasing need for a place to share evaluation results related to space science programs.
3. The need to make available a synthesis of research for non-education experts who work in space science education and public outreach.
4. The lack of access to relevant articles for individuals without institutional subscriptions.

At that point in time, concern 1 was being helped by *Astronomy Education Review* (AER), which provided the central place to publish. Unfortunately it operated only from October 2001 until December 2013.[11] *The Journal of Astronomy & Earth Science Education*[12] (JAESE) debuted a year later as an online, free-access publication under the editorship of Slater. It now fills the need for a central place to publish.[13]

Concerns 2 and 3 are outside of the scope of this paper,[14] but concern 4 is now being answered by iSTAR, the International Studies of Astronomy Education Research Database,[15] which launched in 2017. It is an international collaboration of astronomy education researchers who maintain and continually populate a growing database that can be searched in an almost endless combination. In addition, it has collected hard-to-find theses and other grey literature and made them freely available for download by anyone doing research, a boon to those without access to institutional subscriptions (with the exception of some journal articles held by copyright behind paywalls, for which abstracts are available).

The iSTAR project is led by Dr. Stephanie J. Slater, director of the International CAPER Center for Astronomy & Physics Education Research, in collaboration with Australia's Michael T. Fitzgerald and graduate student Saeed Salimpour of Edith Cowen University's Institute for Education Research, Brazil's Paulo S. Bretones of the International Astronomical Union's Working Group on Astronomy Education, among many others, along with JAESE's Slater and University of Wyoming Ph.D. candidate Tatge.

Thanks to iSTAR, doing a literature search about planetarium efficacy suddenly became much easier and yielded more results, primarily because the database includes access to master's and doctoral theses not normally available and also shares research from grey literature.

Results of my iSTAR research: Highlights of the papers I chose to look at further

A doctoral dissertation titled *The Role of the Planetarium in Students' Attitudes, Learning, and Thinking About Astronomical Concepts* by William R. Thornburgh, 2017[16] was the most exciting find. Dr. Thornburgh, now a postdoc at the University of Louisville, examined "... the role of the planetarium on students while learning astronomy. The main goals of this study were to evaluate changes in students' attitudes towards astronomy, whether students learned and retained more knowledge due to planetarium-enriched instruction, and how the planetarium helped students think about astronomical concepts."[17]

His results: "... the immersive environment and unique capabilities of a digital planetarium positively influenced students' attitudes, learning, retention, and thinking." In addition, he clearly outlines the contributions of his research for planetariums, informal science education researchers, and schools. Because I consider his section on contributions to planetariums and planetarium educators to be so important, I am including the entire statement (page 126):

> The first contribution of this study would be to planetariums and the educa-

7 *A Private Universe* was created and produced by Matthew H. Schneps and Philip M. Sadler, Harvard Smithsonian Center for Astrophysics, in 1988. An excellent article about the program appears at www.scienceinschool.org/2010/issue17/privateuniverse

8 Slater, 2016

9 This trend now appears to be moderating as the practice of Live Interactive Planetarium programs spreads; although never quantified officially, it seems the majority of planetariums include both live/interactive and recorded components. The "wow factor" and existence of pre-recorded fulldome content aided many stakeholders to approve funding for planetarium upgrades, however.

10 Buxner, Sanlyn R. and Bartolone, Lindsay and Fraknoi, Andrew and Plummer, Julia D. and Brinkworth, Carolyn and Schultz, Greg (2015) A Community Discussion about Sharing and Publishing Space Science Education Research and Evaluation. In: Celebrating Science: Putting Education Best Practices to Work. *Astronomical Society of the Pacific Conference Series*, pp 143-147.

11 Learn more about the story of AER in Fraknoi, Andrew (2014) "A Brief History Of Publishing Papers On Astronomy Education Research." *Journal of Astronomy & Earth Sciences Education* (JAESE), 1 (1) pp 37-40.

12 clutejournals.com/index.php/JAESE

13 See the Fraknoi 2014 article in JAESE and also the 2017 Slater-Tatge book for additional publications.

14 Although Concern 3, the synthesis of research for non-education experts, also would be a major benefit to planetarium educators.

15 istardb.org/information.html

16 Thornburgh, William R. (2017) *The Role of the Planetarium in Students' Attitudes, Learning, and Thinking About Astronomical Concepts.* Doctoral thesis, University of Louisville.

17 Ibid, p v (abstract)

(Continues on next page)

tors they employ. The findings of this study have added to the existing data about planetariums, revealing a positive influence on students' attitudes toward science and confirming that students learn more from studying astronomy in a planetarium.

The measurement of learning included additional components that varied from previous research (i.e. retention quiz) and should encourage new studies to evaluate the retention of knowledge over time and to measure learning beyond test performance. This study found that students receiving an embedded planetarium program while learning astronomy outperformed others on a test by a statistically significant margin and exhibited an increased gap by 3.5% on the two assessments, meaning that the treatment group retained knowledge at a higher rate. Planetariums may have an increased interest in working with school groups to measure knowledge, which may lead to the redesign and improvement of field trip offerings.

In regards to capturing the process of learning, rather than learning as a product, the findings of this study indicated that each of the three contexts influenced students' thinking of astronomical concepts. Students were positively affected by the physical space of the planetarium, the activities conducted within the planetarium setting, and with the visualizations projected onto the dome. In order for planetariums to shape student thinking in a positive direction, more experiences (e.g. field trips, exhibits) that will touch each context of the CML[18] should be considered.[19]

Another positive report for planetariums is found in "The concept of spatial scale in astronomy addressed by an informal learning environment" by Anthony Lelliott[20] in Johannesburg, South Africa. He studied how grade 7 and 8 students engaged with the concept of spatial scale before, during, and after visits to both an astronomy science center and a planetarium.

He concludes that "results indicate that, despite contrary suggestions in the literature, students aged 13- to 15-years are able to improve their conceptions of size and distance from naïve and conflicting knowledge to a more scientific understanding after their visit.... The paper argues that a combination of related, themed experiences related to spatial scale can account for the improvement, and recommends that these and even more innovative activities should be explicitly promoted at science centres and in out-of-classroom activities."

Cumhur Turk and Huseyin Kalkan[21] in Turkey wrote in 2014 "The Effect of Planetariums on Teaching Specific Astronomy Concepts" with the goal of determining students' knowledge levels on certain astronomy concepts and the effect of the planetarium environment on teaching. They found "The study results showed that teaching astronomical concepts in a planetarium environment was more effective than in a classroom environment. The study also revealed that students in the planetarium-assisted group were more successful in comprehending subjects that require 3D thinking, a reference system, changing the time and observation of periodic motion than those in control group."

What do planetarians need?

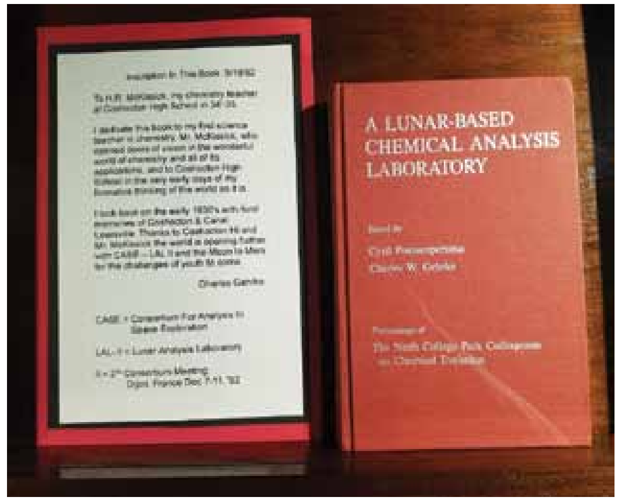
The paper that I personally gained the most knowledge from was "Elementary Student Knowledge Gains in the Digital Portable Planetarium"[22] by Laura D. Carsten-Conner, et. al. In addition to positive results, specifically "Our results suggest that the portable planetarium may be a useful strategy in supporting learners as they struggle with reconciling observed patterns with underlying, non-observable motions of the Earth, and with visualizing concepts such as the speed of planetary orbits relative to their position with respect to the sun," the paper was the only one I found that included a detailed description of the planetarium program itself.

The authors described the setting (a 6-meter dome), the projection system (a digital STARLAB), and the software (Starry Night). The program was interactive and 25 minutes long. A detailed description of the program provided the major points, the sequence it was presented, and the reasoning for the order of topic.

Other research papers describe using the dome in presenting a general topic or in analyzing a specific program, but not the actual presentation itself. For example, teaching seasons is described in "Using a Digital Planetarium for Teaching Seasons to Undergraduates,"[23] but the paper did not describe how the topic was presented under the dome. Another example, "Comparison of Student Learning About Space in Immersive and Computer Environments"[24] looks specifically at one program, *We Choose Space*, and how presenting the program in a dome and on a computer affected retention.

Drilling down to the basics of the presentation, in my opinion, is the best help for most planetarian presenters.

Shannon Schmoll, in her doctoral dissertation "A Comparison of the Effectiveness of Two Instructional Techniques in a Planetarium Setting,"[25] does not study planetarium effi-



On the Origins of Scientists and Engineers, a 1989 study from the Space Policy Institute at George Washington University (Washington DC) is often quoted in pre-digital planetarium research. The authors interviewed a number of scientists and asked why they chose their fields. Occasionally this information is shared in more personal ways, such as the inscription in this book written by a graduate of Cochocton (Ohio) High School and on display in the Cochocton Planetarium. Photo by author.

18 Contextual Model of Learning (CML)

19 Go to ir.library.louisville.edu/etd/2684/ and read the thesis for yourself, or search for it on iStar.

20 Lelliott, Anthony D. (2010) "The concept of spatial scale in astronomy addressed by an informal learning environment." *African Journal of Research in Mathematics, Science and Technology Education,* 14 (3). pp. 20-33.

21 Turk, Cumhur and Kalkan, Huseyin (2014) "The Effect of Planetariums on Teaching Specific Astronomy Concepts." *Journal of Science Education and Technology*, 24 (1) pp 1-15.

22 Carsten-Conner, Laura D. and Larson, Angela M. and Arseneau, Jennifer and Herrick, Robert R. (2015) "Elementary Student Knowledge Gains In The Digital Portable Planetarium." *Journal of Astronomy & Earth Sciences Education* (JAESE), 2 (2) pp 65-76.

23 Yu, Ka Chun and Sahami, Kamran and Sahami, Victoria and Sessions, Larry C. (2015) "Using A Digital Planetarium For Teaching Seasons To Undergraduates." *Journal of Astronomy & Earth Sciences Education* (JAESE), 2 (1) pp 33-50.

24 Zimmerman, Laurie and Spillane, Stacia and Reiff, Patricia and Summers, Carolyn (2014) "Comparison of student learning about space in immersive and computer environments." *Journal and Review of Astronomy Education and Outreach,* 1 (1) A5-A20.

25 25 Schmoll, Shannon Elizabeth (2013) *A Compar-*

cacy as much as she does two teaching method frameworks. She does, however, conclude that students need adequate preparation and classroom support to get the most from their informal education experience. In suggesting revisions to the SMILES (School-Museum Integrated Learning Experiences in Science) framework, one of the two she studies, she says[26]

> These revisions included addressing choice and control normally seen in museum settings in the classroom, preparing students for language in addition to concepts seen while on a field trip by providing teachers with a script or list of vocabulary to be addressed in context, have students collect data from the show and explicitly use it with scientific practices the classroom afterward to support multiple exposures to ideas and help them avoid using authority of facts gathered at the planetarium as a sole means of justifying answers, model specifically those scientific practices in the classroom, and address a single overarching topic in planetarium show[s] or delineate changes between topics to avoid confusing students.

The points noted in this sentence are all usable suggestions that planetarians can take advantage of, especially the need to address a single topic, and, if more than one topic is included, to clearly let the students know when a topic change is taking place.

Planetarians need to contribute

Despite often being forgotten in planetarium education research, we under-the-dome planetarians have made many contributions to the field and continue to do so at each of our conferences. We do this by giving papers, which are then collected in conference proceedings. Until just recently, conference proceedings were not considered as appropriate sites for research because of the lack of peer review.

Returning to Slater and Tatge's *Research on Teaching Astronomy in the Planetarium*: (page 11)

> Due to the surprising lack of empirical research reports in scholarly peer-reviewed journals related to planetarium education research, much of the research is found within grey literature (Slater 2015.) Additionally, one of the journals central to planetarium education research, the *Planetarian*, publishes both peer-reviewed and grey literature mixed together without a clear distinction between the two."[27] In order for a work to qualify as "peer-reviewed," reports reviewed required an abstract, a listed accepted/published date, and one or more sections considered a methodology, literature review, or program evaluation with empirical results. For a research report to be classified as "grey literature," it needs to fulfill one or all of the following criteria: no abstract, no bibliographic citations, a conference proceeding, poster, or presentation. Since a large portion of publications relating to planetarium education research usually describe the subject in a general manner, they were categorized within the program/curriculum report or description domain as long as they were not considered formal reviews of the literature. Also classified within this category were any works that described a new activity or planetarium.

Even though the adjective "empirical" means something based on or verifiable by observation or experience rather than theory or pure logic, in educational research empirical research relies not only on the observable, but also on the measurable. This translates to methodologies: quantitative, qualitative/interpretive, and mixed-methods.[28]

The subset of people who work under the dome who are able to conduct empirical research at the peer review level, especially within the requirement listed above, is fairly small; most (but not certainly all) of their names have been mentioned in this paper or in the endnotes. This leaves a large number of people making daily observations that are valuable to their peers, some of whom then share their observations, best practices, novel ideas, and other insights at conferences and in planetarium affiliate newsletters.

Here are research resources just waiting to be mined for data to share. There is *Planetarian*, of course, but also IPS conference proceedings and affiliate proceedings from around the world. Our resources are primarily grey literature, and iSTAR is willing to accept our contributions. As it states on the iSTAR website: "We challenge all communities of astronomy education researchers to use the iSTAR database to develop and extend collaborations; inform policy, funding and educational decisions; and share in the voice, perspective and experience of astronomy education research. Please join us by uploading any and all works related to astronomy education research!"[29]

Sources ready to be data mined

Our job is to scour our publications for papers that deserve to be shared with wider audiences, instead of being hidden on our websites or shelves. Perhaps seek an astronomy education researcher from within your ranks to assist in deciding the suitability of the wider dissemination. Use the "iSTAR Database Document Categorization Scheme" that appears on page 12 of Slater's article in the December 2017 *Planetarian*, or on pages 8-11 in the *Astronomy Education Research in the Planetarium* book.

Although the upload section of the iSTAR database website might appear daunting, do not let it stop you. The categories most applicable to planetarium grey literature are fairly clear, and you do not need to fill in every line:

- Document source: grey literature
- Type of resource: curriculum or program evaluation, curriculum description or report, position paper or editorial, and historical
- Empirical methodology: applies only to empirical studies
- Learning environment: informal
- Research setting: nearly all of the settings listed, with the possible exception of research facility
- Study participants: all apply
- Construct: your decision, but probably general teaching strategies and perhaps nature of science
- Scientific content focus area: all apply
- Demographic focus: all apply
- The final two categories, language of publication and location study conducted, are self explanatory.

Summary

There is a tremendous amount of valuable information in the planetarium community's conference proceedings. Although it might not be possible for planetarians to perform empirical research, we certainly can add to the literature to help astronomy education researchers by taking advantage of the iSTAR Database. ☆

"Man's mind and spirit grow with the space in which they are allowed to operate."

– Krafft A. Ehricke, rocket pioneer (Spacequotations.com)

ison Of The Effectiveness Of Two Instructional Techniques In A Planetarium Setting. Doctoral thesis, University of Michigan Ann Arbor.

26 26 Ibid, abstract

27 This lack of distinction has changed over the past several years to make it clear which articles are reviewed - Ed.

28 Slater-Tatage (2017) p 12.

29 istardb.org/information.html