Use Of Formative Assessment-Based Active Learning By Astronomy Educators Teaching In Live Planetarium Learning Environments

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ABSTRACT

Planetariums were created to teach astronomy by simulating motions of the star-filled night sky; however, simply having a virtual reality facility to immerse learners beneath a projected night sky in and of itself is insufficient to automatically ensure student learning occurs. Modern teaching strategies, like active learning, have consistently shown to move students toward deeper understanding in classrooms; yet, active learning approaches seem to be only rarely observed in planetariums. Use of Ruiz-Primo and Furtak's (2006) coding scheme to define and analyze formative assessment conversations between classroom teachers and students reveals that unless teachers are formally taught how to use formative assessment-based active learning, such approaches are largely absent in classrooms studied. The goal of this 2-phase study was to evaluate the nature of active learning-based formative assessment conversation cycles in the planetarium. The first phase systematically analyzes 26 recordings of live planetarium programs to describe and document presence of active learning teaching strategies. The second phase conducts interviews to determine rewards and barriers to using formative assessment-based active learning in the planetarium. Analysis suggests scant evidence of complete formative assessment conversation cycles, despite that varying degrees of interactivity between the planetarium lecturer and the audience do exist. It is not that planetarians don't ask questions, but responses rarely serve to systematically guide instructional decisions aligned with modern pedagogy. Moreover, these planetarians hold a wide range of definitions of what constitutes active learning and often view their primary responsibility as inspiration rather than education, lending explanatory power to why active learning is largely absent.

Keywords: Discipline-Based Astronomy Education Research; Planetarium Education; Active Learning; Formative Assessment

The planetarium has long been heralded as a promising non-traditional learning environment for teaching astronomy. Essentially a first-generation "virtual reality" education facility, the first planetarium was built in 1930 using a central light source surrounded by an opaque sphere with small holes that projected images of tiny stars on a curved hemispherical screen stretching over the audience's heads. Chandler (2010) reports that more than 500 planetariums were quickly constructed in the United States during last mid-Century's space race, many of them as proud additions to public school buildings. Today, more than 4,000 planetariums exist worldwide, (Abbatantuono, 1995; Petersen, 2018).

Traditionally, planetarium educators focused largely on teaching the predictable motions of sky objects at differing latitudes. Planetariums were used by schools, universities, naval and air military academies, and museums for teaching complex topics of celestial navigation and time keeping at academically high levels (Slater & Tatge, 2017). In contrast, today's modern, video-based planetariums are more often used to teach contemporary astronomy topics or feature other science-focused programs which are only distantly related to astronomy. In sum, planetariums have become high-tech virtual reality theaters capable of presenting highly visual information on any number of topics.

As with museums, planetariums have long been popular field-trip destinations for public school groups. While planetariums are tacitly considered by many to be the best place to learn astronomy topics, it is becoming increasingly

difficult for financially strapped school districts to justify field trip expenses of any type as high stakes testing and teacher accountability have increased pressure on educators at large to focus on meeting clearly specified curriculum standards and measurable learning outcomes. Educators might benefit greatly if they can better describe and document how the planetarium learning experience—and the effective teaching strategies employed by planetarium educators—can help improve overall student outcomes.

There is a long history of studying the nature of teaching and learning in the planetarium, though the vast bulk of studies done have most often focused on impact evaluation, rather than any systematic discipline-based science education research (*viz*., Slater & Tatge, 2017). Perhaps most well-known research study across science education when talking about planetarium education, Bishop (1980) conducted a two-group, pre-test/posttest comparison study of the impact of planetarium education on student outcomes at the behest of school districts. Her seminal research showed that employing purposefully implemented learning cycles—the premiere active learning teaching strategy of the time—did measurably improve student achievement. The dominant feature of those learning cycles was that the instruction was largely student-centered and focused on the student experience with phenomena. This work was considered groundbreaking at the time; however, her approach did not emphasize the aspects of modern active learning popular today, such as those that leverage formative assessment in support of student metacognition and to drive instructional decisions. Modern teaching theory suggests active learning, which is based in part on historical work on learning cycles, is often advocated as a best practice to improve student learning and achievement, especially when it includes a focus on formative assessment. What remains to be seen is whether modern approaches to active learning are widely being used in planetarium education and under which conditions planetarium educators might be taking advantage of the well-documented benefits of using active learning teaching strategies. If planetarium educators can demonstrate the extent to which they are using contemporary teaching strategies, they might be able to increase their perceived value and marketability as a unique educational experience provider.

Bonwell and Eison (1991) argue convincingly that using active learning strategies leads to improvements in student thinking and attitudes in a wide variety of learning environments. Students who engage in active learning and think about what they are doing and learning (metacognition), tend to learn more and retain the information longer (Francis, Adams, & Noonan, 1998). One core aspect of contemporary active learning that differentiates it from its earlier teaching innovations is its ability to enhance learning by promoting timely feedback to students regarding their learning and progress through a focus on formative assessment (Slater, 2020; Slater & Lee, 2006). Formative assessment—assessment for learning, not of learning (Black, 1993) - is designed to both provide the continuous feedback to students on their understanding and help inform teaching since the teacher can also guide instructional pacing, depth, and review based on the information gained by asking students questions and acting on their responses (Bell, 2000; Bell & Cowie, 2001). In this way, a focus on formative assessment informs the teacher of student understanding in real time, thus allowing the teacher to adjust delivery. In this sense, formative assessment is a tool in the hands of a talented educator that provides valuable feedback to the instructor to make instructional decisions and feedback to students on how their learning is progressing. Because planetarium educators drive instruction primarily by oral presentation, it seems natural that active learning in planetarium environments could readily take the form of teacher-driven assessment conversation cycles.

In recent years, Neece, Sayle, Nyela, and Boyette (2013) investigated implementation of active learning strategies in live planetarium programs as indicated by evidence of interactivity between the presenter and the audience and found moderate evidence of teacher-driven questioning. What was missing from their work was any evaluation of the nature or purpose of audience interactions. The looking for evidence of "oral interactions" by Neece et al. (2013) study serves as a solid first step in studying the nature of conversations existing in planetarium presentations by investigating the amount of verbal exchanges but lacks any insightful critical analysis in the quality of interaction or the extent of learning derived from planetarium educators' efforts. One way researchers might get a better feel for the quality of the informal formative assessment practices in these presentations is to consider a more extensively developed framework of assessment conversation cycles, like those advocated widely by Duschl and Gitomer (1997) and, in this particular context, Ruiz-Primo and Furtak's (2006, 2007) well-documented ESRU assessment conversation cycles (Ruiz-Primo, 2011). In other words, there has yet not been significant work looking at the specific nature and content of interactions between planetarium lecturers and their audience. Knowing the substance of interactions between educators and learners helps to more fully describe and document a learning experience.

Formative assessment does have identifiable characteristics that can be systematically defined and observed. Ruiz-Primo and Furtak (2007) looked specifically at active learning in the elementary and secondary level classrooms in the context of formative assessment conversation cycles. Through systematic observation, they came to define complete formative assessment conversation cycles as what they called complete ESRU cycles of interactive teaching. Their framework is as follows: In "ESRU cycles - the teacher Elicits a question; the Student responds; the teacher Recognizes the student's response; and then Uses the information collected to support student learning" (p. 57). The key piece of the ESRU cycle is the U, using the information to guide and support student learning. This using takes feedback to a deeper level beyond simply evaluating student contributions as right or wrong. What they found was profound—those teachers whose assessment conversations were more consistent with the ESRU cycle had students with higher levels of performance (Ruiz-Primo & Furtak, 2006).

One might say that planetariums are in and of themselves such a great facility that planetarium lecturers need do nothing but turn on the projector and get out of the way because learning will naturally happen on its own. This perspective—based on an idea that a trained and talented planetarium teacher is unnecessary—seems short sighted. If instead, planetarians employ modern teaching strategies, including ESRU, then any advantages granted by the unique nature of a planetarium facility might be amplified even further. To this end, an outstanding question exists about the nature of planetarians' teaching interactions with their audiences and specifically whether planetarium educators are already implementing active learning in the form of these formative assessment conversation cycles to implement modern active learning teaching strategies in the planetarium, and moreover, whether there is room for improvement in the planetarium learning environment. In their studies of ESRU assessment conversation cycles used among licensed and certified STEM classroom teachers, Ruiz-Primo and Furtak (2006, 2007) observed woefully incomplete ESRU conversation cycles to be widespread. What they report is not that teachers neglected asking their students questions, it was that teachers were not using students' responses in a substantive way to guide instruction. Complete ESRU assessment conversation cycles where students' answers to teacher-directed questions seem to matter showed up in only about one-fourth of the classrooms observed. The abundant lack of complete ESRU cycles among licensed and certified educators who are supposedly trained in the appropriate and liberal use of formative assessment as a foundational teaching strategy, suggests that low use of complete ESRU assessment cycles might likely be observed among planetarium educators who are not necessarily trained in assessment strategies. If an absence of foundationally good teaching strategies is missing in live planetarium programs, this represents a ready opportunity for targeted professional development to improve the widespread effectiveness of planetarium education overall. In the same way, if planetarium educators' approaches to teaching in the planetarium can mirror that of typical classroom teachers, which this study assumes they can, then it holds that targeted professional development focused on ESRU cycles might also improve the teaching of planetarium educators. What still needs to be determined is whether planetarium educators are leveraging the learning power afforded by formative assessment-based active learning strategies among planetarium educators.

Theoretical Framework

The theoretical framework of this study is focused on the use of language as a vital component of guiding learning; thus, the study is framed within the context of teaching via active learning. This framework is grounded first and foremost in Vygotsky's (1987) theory of learning which argues that meaning is obtained largely through language. Since the main modality planetarium educators use to interact with their audiences is through their voice and, potentially, in the form of conversations, planetarium educators might naturally be more poised to enhance their chosen teaching methods in terms of their voice and language use than in any other aspect of a planetarium learning experience.

Dewey (1938) advanced the notion that learning is a social and interactive process and students should take part in their own learning. For planetarians, therein lies an opportunity to combine the power of language framed by Vygotsky (1987) with Dewey's notions of learning as having interactive and social components. It is worth noting that Dewey's approach to instruction was still highly teacher-centered, even though the approach took into consideration what students were doing during instruction. He advanced the idea of experiential learning which was a steppingstone to the modern teaching theory of active learning. This gets us much closer to the modern notions of active learning, as broadly defined by Bonwell and Eison (1991). Bonwell and Eison (1991) defined active learning as anything that,

"involves students in doing things and thinking about the things they are doing". This concept somewhat transitions away from Dewey's teacher-centered instruction toward a more student-centered approach and emphasizes timely learning feedback and supporting students' metacognition.

Rising in prominence above other educational innovators of his time, Lemke (1990) constructed a purposeful approach of highly structured learning cycles to include Initiate, Respond, Evaluate/Feedback (IRE/IRF) which provided the much-needed feedback to students on their learning as it happened; however, it did not emphasize anything beyond the evaluative/feedback stage. In this framework, it is not enough for students to know whether their thinking is right or wrong, but to understand why and to use that information to advance learning and understanding into novel situations. In 1997, Duschl and Gitomer widely proposed these cycles be used to help teachers gather information about student understanding and further guide student learning. They introduced the notion of the assessment conversation as "structured discussions in which student products and reasoning are made public, recognized, and used to develop questions that can (a) promote conceptual growth for students and (b) provide assessment information to the teachers" (Duschl & Gitomer, 1997; Duschl, 2003).

In this sense, assessment conversations are a form of formative assessment actualized during teaching to guide instructional decisions in "real time." Formative assessment involves gathering, interpreting, and acting on information about students' learning so that it may be improved (Bell & Cowie, 2001; Duschl, 2003). Ruiz-Primo and Furtak (2006) adopted this idea of assessment conversations as being the daily instructional dialogues that embed assessment into an activity already naturally occurring in the classroom. They developed a framework to study assessment conversations in STEM classrooms which they named the ESRU cycle, "based on the idea that informal formative assessment can take place at any level of student-teacher interaction in the course of daily classroom talk" (Ruiz-Primo & Furtak, 2006). This approach to active learning promises great potential to be a natural fit for the planetarium educator, as it requires no additional technology or materials, and it focuses on the main vehicle for instruction in the planetarium environment: the presenter's and audience's voices and talent at adjusting instruction based on students' responses.

Recognizing the current focus on assessment and science education reform and undergirding the theoretical framework of this project, Shavelson et al. (2008) sought to formally embed formative assessments into nationally used curriculum. To support widespread implementation of formative assessment, they created model of formative assessment as a continuum on which formative assessment strategies fall. This continuum is comprised of three anchor points: (a) "on-the-fly," (b) planned-for-interaction, and (c) formal and embedded in curriculum (viz., Ruiz-Primo & Furtak, 2007; Shavelson et al., 2008)" (p. 300). What this research in total says to educators is consistent and profound—learning benefits dramatically if teachers are inclined and equipped to give students meaningful feedback about what they are learning. It is through this lens that active learning through intellectual engagement and supported by frequent formative assessment influences learning that frames this study.

Research Questions

If learning is consistently enhanced in conventional classrooms using active learning teaching strategies, such as modern active learning, then one naturally wonders if these techniques are being successfully translated into live planetarium learning spaces. In response, the overarching goal of this study is to better understand the use of active learning strategies—formative assessment conversation cycles specifically— in planetarium presentations for the purpose of improving learning and the educational value of a planetarium visit. In order to do this, the first step is to acquire a baseline sense of what is already happening in planetarium presentations in terms of the extent to which active learning strategies are commonplace. The second step is to understand the underlying mechanisms and influences of why what is observed is occurring. The research questions guiding this study are:

- What is the extent of formative assessment as part of active learning in live planetarium presentations observed as measured by the presence of assessment conversation cycles?
- Which factors could be influencing the relative use of assessment conversation cycles in planetarium presentations?

Once the current extent of formative assessment-oriented active learning strategies among planetarium educators is better understood as well as what is influencing this, steps could be taken to develop opportunities for professional development to help address factors that might be serving as barriers to using assessment conversations, or to further encourage their use. The ultimate goal of this work is to expand the quantity and quality of modern teaching techniques, specifically active learning strategies, in planetarium teaching to improve understanding and retention for a wide diversity of students and provide value to planetarium stakeholders.

METHODS

This study leverages an exploratory, sequential, mixed methods design (Thomas, 2017) to investigate the nature and prevalence of formative assessment-oriented active learning occurring in live planetarium lectures. As the first of a two-phase study design, the quantitative aspect of this study involves systematic structured observations of planetarium presentation recordings. The audio recordings were analyzed within the framework of looking for evidence of active learning in the form of informal formative assessment, and evidence for assessment conversations (ACs) in particular. In this study, recordings were coded by identifying a particular active learning instructional dialogue cycle, the ESRU assessment conversation cycle (Ruiz-Primo & Furtak, 2006, 2007). Evidence for both complete and incomplete cycles was quantified for a collection of planetarium presentation recordings, with each cycle categorized by an inquiry dimension: epistemic, conceptual, or non-inquiry. As a second phase of this study, clinical interviews were conducted to determine what barriers, if any, planetarium educators encounter when trying to interact with students by using active learning teaching strategies in the planetarium during live presentations. The interview results were inductively coded to look for emergent themes.

Participants

Planetarium educators from across the U.S. were recruited to voluntarily submit audio recordings of their own planetarium presentations during 2017-2018. To the best of our knowledge, the wide-scale collection of recorded live planetarium lectures from across the U.S. has never been done before. One cannot understate how difficult it is to acquire a large number of useable recordings of this nature. By using a purposeful sampling-based, participant selection process involving cajoling volunteers through personal networks, contacts made at professional conferences, and social media solicitations, it was hoped to solicit the most likely candidates who might most clearly exhibit active learning in the planetarium—or at least believe that they are using active learning techniques. It should be acknowledged that this approach somewhat risks the wider generalizability of the study by potentially attracting active-learning implementers and perhaps biasing the study sample, but it was judged that any amplified "signal to noise ratio" was worth the trade off in order to capture these 'first-light' observations on planetarian teaching behaviors in situ.

Fourteen of the volunteering planetarium presenters selected for this study self-identified as men and 12 self-identified as women representing a wide range of experiences and formal college course backgrounds, including being certified teachers. Their demographic profiles mirror the overall demographics of U.S. planetarium educators overall (viz., Schultz & Slater, 2020)

DATA COLLECTION & ANALYSIS

Phase 1: Analyzing Presentation Recordings

For this study, a subset of 26 recordings were selected for coding using an ESRU coding scheme developed by Ruiz-Primo and Furtak (2007) to look for evidence of active learning. Each assessment conversation within the recordings was coded as complete or varying levels of incomplete (i.e., ESRU vs. E, ES, or ESR) carefully following the protocols designed and widely used by the developers. The mean recording length analyzed was 41 minutes. The recordings were quantitatively analyzed and categorized by number and frequency of ESRU cycles per minute. Frequencies were further analyzed by normalizing the data as assessment cycles per 30-minutes of recording to account for variations in show length. For shows containing both live presentation and pre-recorded content, only the live component was counted toward the show length and used for normalization.

At the outset, substantive limitation identified for this study design involves the use of the ESRU coding scheme as applied to the planetarium setting. The ESRU coding scheme was developed to analyze assessment conversations in STEM classrooms (Ruiz-Primo & Furtak, 2006, 2007) and validated in that setting, not for the informal education environment of planetarium presentations per se. While the planetarium can be thought of as a "modified" or "non-traditional" classroom, the potential threat to validity is whether it is appropriate to apply this scheme developed for formal learning settings to planetarium presentations that happen once and last upwards of one hour, unlike classroom sessions which are a regular occurrence with a teacher that is well known to the students. Consistency of applying the code is likely also a limitation but is mitigated through the use of constant comparative analysis (Thomas, 2017) of the coding, and by monitoring interrater reliability.

Phase 2: Interviews

As a second phase after systematic coding of the recorded presentations, specific participants were identified for member checking based on their level of active learning, and in particular ESRU assessment conversation cycles. The study design uses a semi-structured interview approach to investigate the possible factors impacting the planetarium educators' levels of ESRU use and employs constant comparative analysis to examine the interviews for emerging themes (Creswell & Creswell, 2018). The goal of the interviews was to make sense of whether the recordings represent a 'typical' level of assessment conversation use or not, what factors might impact the presenter's use of assessment conversations during presentations, and under what conditions or training might this change. The interviews were conducted by the lead researcher via desktop videoconferencing and field notes were collected during the process. This phase of the research is based on a theoretical framework of naturalistic inquiry and emphasizes that the themes are largely unknown to the interviewer a priori (Creswell & Creswell, 2018). The goal here is for the results to naturally emerge from the collected data itself.

RESULTS

Results From Planetarium Recordings

ESRU assessment conversation cycles were used as proxies for active learning for at least two reasons. The first is that many planetarium presenters "ask questions" of their audience—most of the time such questions are rhetorical-performance questions in that no audience response is anticipated and many other times the questions are "are you with me?" pacing-style questions. The second reason is that real active learning—framed by constructivist teaching principles—is driven by the learner, and teacher-posed questions are expressly for the purpose of guiding instructional decisions, not as part of the presentation performance. In this case, if a planetarium teacher poses a question, but does not use the response in any meaningful way, then the learning environment can have the facile appearance of a learner-centered, active learning environment, but not actually be one.

Although many presenters posed questions to their audiences—665 questions were cataloged in the 26 recordings analyzed for this study representing a broad swath of planetarium teaching scenarios—10 of the 26 (38%) recordings had no instances of a complete ESRU assessment conversation cycle (i.e., no U-scores) at all. Nine of these 26 recordings had only one or two instances of U's, five of 26 had three to six instances, and there were only two of the 26 that had six or more U instances.

Figure 1. Raw Frequency of Complete ESRU Assessment Conversation Instances

Instances per Recording	Recordings (n=26)	Percentage	Frequency
0	10	38%	Never
1-2	9	35%	Rarely
3-6	5	19%	Common
> 6	2	8%	Highly Frequent

At the extremes, the largest number of U's observed in one single recording was 16 separate U-instances in a 48-minute recording. To account for time differences, the normalized U-score (<U>) is calculated as number of U-

instances observed per 30-min. For the 48-minute recording with 16 separate U-instances observed, the normalized U, <U>, is 10. Thirty-eight percent of the recordings had no instances of complete ESRU assessment conversation cycles and another 35% had only rarely observed U-instances (1-2) per 30-minutes. In considering the number of observed U-instances normalized to a 30-minute presentation, more than three-fourths of the recordings contained little to no U-instances per 30 minutes (the categories of 0 U's & 1-to-2 U's). Combined together, this leaves 15% of the recordings having commonly observed U's per 30 minutes of 3-6, and only 8% with 6-10 U's per 30 minutes. In short, similar to what Ruiz-Primo and Furtak (2006, 2007) observed in K-12 classrooms, complete ESRU assessment conversation cycles seem to be quite uncommon in the planetarium recordings analyzed, implying that actual active learning in the planetarium learning environment could be exceedingly rare at best. Given the potential bias in the way the sample was constructed—volunteers knew that the lead researcher was looking for evidence of active learning in the planetarium—any speculations about the nature of the larger planetarium education community in general could be more dire.

Correlations Between Presenter Demographics And Complete ESRU Cycle Level

Given the lack of ESRU assessment conversation cycles—U-instances—evident in the data overall, one wonders if there are specific scenarios where U-instances are more or less prevalent. In terms of presenter's biological sexual identity, the average number of U-instances normalized to 30 minutes (<U>) did not vary significantly between males and females. The average <U> for females was numerically higher than that of male presenters, 1.8 and 1.5 respectively, but not statistically significant at any level. The highest <U>-score for the female presenters was 10, for the males it was 8, and for both the next highest, the score was only 4 U's. Of all the recorded presenters analyzed, one of each sex had high numbers of normalized U-instances showing complete ESRU assessment conversation cycles. Neither statistically nor qualitatively by inspection, does there seem to be any correlation between self-identified sex of the presenter and the presence of complete ESRU assessment conversation cycles. The same non-statistical significance goes for years of planetarium teaching experience and is outlined in exhaustive detail elsewhere (Schultz, 2020).

Analysis Of Eliciting Question Domains

In addition to systematically coding what occurred during planetarium presentation recordings for the completeness of assessment conversation cycles, the initial step of the conversation cycle–what Ruiz-Primo and Furtak termed as the Elicit step–was analyzed. This was judged to be an important first step for the researchers to better understand the sort of questioning that was going on. Proffered questions were categorized into three broad categories: epistemic, conceptual, or non-inquiry/rhetorical. This last category is particularly important for removal and cleaning the data set as some questions aren't actually substantive teaching questions, but instead are rhetorical, managerial, or vague (e.g., Do you understand? Everything ok? How are you feeling?) and such questions wouldn't be appropriate to analyze for this study. Similarly, those non-leading questions where the presenter left no time for answers, asked questions that were unrelated to scientific knowledge or concepts, or that were clearly rhetorical were marked as the third category.

Epistemic questions are those questions focused on the process of what we know or can learn through scientific investigation— "what do you think…?" and "how can you know?". Questions categorized in the epistemic science learning domain are those which refer to the knowledge and understanding of science and how this understanding can be used to justify scientific claims (Yang et al., 2018). Epistemic questions are evident when learners are asked to make predictions, pose hypotheses, suggest needed observations, or interpret data in the service of creating evidence based on observations. In contrast, a second broad category of questions that could be asked are "conceptual domain" questions. Conceptual questions are those in which the learner is asked to use a scientific model to explain an outcome, create examples and counter examples of a physical process, or explain a specific scientific notion by way of an apt analogy.

In this study, six hundred sixty-five (665) opening questions were categorized. Of the 665 eliciting questions recorded, 279 fell in the epistemic domain and 258 of the opening conversation cycles were conceptual in nature. The remaining 128 were of a non-inquiry/rhetorical nature.

Results Of Phase 2 Follow-Up Interviews – Emergent Themes

When considering the entirety of the study's second phase interview data, four consistent themes emerged from a constant comparative analysis of the field notes from eight interviews. These themes shed light on of the mechanisms and barriers related to successfully implementing formative assessment-based active learning in the planetarium. The dominant themes were: (1) Most planetarium educators interviewed stated their main goal as a presenter is to engage, excite, and inspire their audiences and that they try to do this through a focus on increased interactivity. (2) While planetarium educator's main goal was to inspire, some participants used their conceptions of active learning and interactive engagement for various other purposes. (3) Active learning and interacting with planetarium audiences takes many forms. (4) There are perceived limitations to how and what kind of active learning and interactivity planetarians use in their presentations. In discussing active learning and how they interact with their audience in practice, the planetarium educators emphasized that interacting with their attendees was a priority and suggested it could take different forms.

When asked about their goals as a presenter for their planetarium presentations, the majority of the planetarium educators expressed that they were not as concerned with their audience members coming away with specific content knowledge, but rather hoped that audience members were inspired to learn more, as well as recognizing that audience members actually know more than they thought and building on that knowledge. These results are consistent with earlier work by Plummer and colleagues (Plummer & Zahm, 2010; Plummer, Wasko, & Slagle, 2011; Plummer, Kocareli, & Slagle, 2014; Plummer, Schmoll, Yu, & Ghent, 2015). What is observed is that these planetarium educators were more concerned with their audiences being inspired and entertained than with their audiences learning astronomy concepts. One planetarian expressed her desire to inspire people to use the planetarium experience to "get people outside and look up" so they can connect with the real sky. They report being "interactive" in order to open up communication between them and their audiences and helps the audience feel more comfortable.

This emergent interview theme goes a long way to explain why formative assessment-based active learning in the form of assessment conversation cycles might have been largely missing from the vast majority of planetarium presentation recordings analyzed in the initial phase of this study. If learning new astronomy concepts is not the primary focus of a planetarium lecture, then there is little reason to expect that these planetariums would be using contemporary pedagogies. Moreover, this unexpected result potentially has profound implications for some mismatched expectations if visiting school groups are depending on planetarium lecturers to focus on teaching concepts rather than expecting the primary objective of the visit to be one of being inspired, motivated, and entertained.

For classically trained educators, active learning has a specific meaning and usually leans on a learner-centered approach to teaching. Active learning ideas are long standing and are often attributed to thought-leader David Ausubel who passionately argued that the principle job of a teacher was first and foremost, "to ascertain what the student already knows and teach them accordingly" (Ausubel, Novak & Hanesian, 1968). For other educators and outreach enthusiasts, active learning might instead be considered a broad term open to considerable interpretation, and perhaps in the present context being synonymous with "interactivity." For the planetarium educators in this study, the notion of interactivity—a word that interviewees used frequently in the phase two interviews—seems to describe more of a mentality or approach to presentation rather than a specific teaching method.

When synthesizing all of these perspectives into a single emergent theme, what is most fascinating is the repeated notion of the planetarian's approach to presentation leveraging interactivity. By being interactive, they say that they are leveraging the benefits of 'conversations.' As a result, this emergent theme is promising for increasing the prevalence of active learning in the planetarium. Although the planetarians studied here did not exhibit formal formative assessment in the form of complete assessment conversation cycles, the planetarians did appear to be at least predisposed to conversations as a starting place and a teaching technique. One interpretation of planetarians' inclinations toward interacting with their audiences through conversational-style presentations could be that making a move toward active learning through assessment conversation cycles is not actually a giant leap.

Not discounting that active learning and interactivity are different things, interviews consistently confirmed that simply being in a planetarium environment comes with its own challenges. Planetarium presenters report encountering

barriers to implementing the extent of interactivity they desire. Across all the interviews, participants agreed that scarce time is a big issue when thinking about being interactive with audiences. For one, astronomy is a vast subject to cover in 45 minutes. For another, planetarians frequently receive requests from the patron teacher leaders who bring their students to the planetarium for the specific content they wish to have discussed. These teachers typically want presenters to cover as much content as they possibly can in the time allotted for their visit. In other words, if the teacher leader wants students to learn about comparative planetology and the students want to learn about black holes, this presents a conflict for the planetarium presenter. Taken together, there is a limit on how much the audience can drive the content coverage, which can be challenging for presenters, especially if they want to slow down and honor conversations with their audiences. Several of the participants agreed that too much content is often an issue and would prefer to cover just a few topics in depth than all the content of astronomy quite shallowly.

DISCUSSION

Given a starting posture that active learning is a desirable teaching strategy to observe being done in the planetarium, the findings of the first part of this study of planetarium program recordings using systematic observations suggest there is scant evidence for widespread active learning approaches going on in planetariums, insofar as this study design can reach. Moreover, when exploring the type of active learning that takes the form of formative assessment that guides instructional decisions—specifically terms of Ruiz-Primo and Furtak's (2006) ESRU-cycle assessment conversations—there is almost no evidence that planetarium educators are aware of, let alone employ purposefully, assessment conversation cycles where instructional leaders ask questions and then use learners' answers to guide instruction in planetarium teaching scenarios. In short, very little active learning when defined in terms of formative assessment characteristics appears to be going on.

It is not that planetarium lecturers studied aren't attempting to be highly interactive by asking the audience questions. Far from it. Most of the recordings did show that the planetarium lecturer would ask the audience questions - 665 posed questions were analyzed for this study. However, what we did not observe is that the audience's response had any significant bearing on the instruction. What was observed in this study of 26 systematically analyzed recordings - including 258 conceptual questions and 279 epistemic questions in the analysis - was that about 1/3 exhibited no instances of complete assessment conversation cycles (ESRU cycles), and another 1/3 exhibited only one or two complete assessment conversation cycles, normalized to 30-minutes of presentation. Taken together, these results point strongly toward the answer of research question number one about the extent of active learning in the planetarium in the form of formative assessment to be "highly limited."

In the second phase of this research, four dominant themes repeatedly emerged from the constant comparative analysis of semi-structured interviews with eight of the study participants that focused on trying to uncover the mechanisms and barriers related to active learning in the planetarium. Most dominantly, the study participants interviewed often used the vague term "interactivity" insofar as they hoped it would enhance their teaching goal to engage and excite their audiences. These results are consistent with interview work done by Small and Plummer (2010) who report the planetarians in their study most frequently point toward promoting interest as their leading priority when teaching children. This is in stark contrast to expressing first and foremost a desire for attendees come away with a plethora of new factual, epistemic, or conceptual knowledge. Such statements as observed in the interviews imply that these planetarians do not often see knowledge enhancement as the most important part of their job. It seems to be that planetarium educators interviewed in this study believe that the responsibility for "teaching astronomy" largely lies not with themselves but with the attendees' classroom teacher. This was also true of those presenters who were doing non-school-based general public shows—the planetarium was to inspire, excite, and motivate primarily and the teaching of concepts was a distant second. Certainly, the specific goals of planetarium presenters impact the instructional decisions they make.

This transferred assignment of responsibility for teaching concepts has some rather profound implications. Planetariums and museums by and large promote their facilities and their programming first and foremost as educational. School districts who go to considerable expense to provide planetarium learning opportunities for their students most often justify the expense and time away from the traditional classroom based on a notion that students will learn concepts better in the planetarium than in the classroom. One naturally wonders if there is a mismatch

between how planetarium educators see their responsibilities and the expectations school districts have of what is happening in those facilities. On one hand, it is possible that the planetarium educators selected for this study are somehow special and unique in that they believe their job is to inspire, and that planetarium educators who clearly have learning at the center of their presentation goals might have a very different approach to instruction. On the other hand, it is plausible that planetarium educators believe - and plenty of education research cited earlier backs up this position—that a 30- to 45-minute isolated learning engagement is insufficient to dramatically change the fundamental conceptual understanding of its attendees.

The second emergent theme, that active learning and interactivity is used for more than just teaching speaks to the far-ranging notions of what the actual domain of active learning is among planetarium educators, as well as possibly the lack of a deeper understanding behind the purpose and benefits of an interactive experience in the first place. For one, there was no reticence on the part of the interviewees to point to interactivity as a behavioral management strategy. For another, the interviewees by and large thought their audiences would enjoy the experience more if they were having conversations with them instead of serving as a firehose of facts. These goals are laudable; however, these goals do not speak specifically to active learning, or even learning specifically. What is clear is that although participants widely claim that interactivity and active learning is important, it seems that they might be mistakenly using the terms “interactivity” and “active learning” interchangeably. It has long been documented that nascent K-12 teachers mistakenly interchange the terms “hands-on” and “active learning” as being equivalent (viz., Sandholtz, 2011). Wiggins, Wiggins and McTigue (2005, p.16), among others, eloquently argue that a common problem of interactive experiences for the sake of interactivity and activity may “lead only accidentally, if at all, to insight or achievement”. In other words, what these authors are saying that is likely occurring here as well is that interactivity for the sake of interactivity might be fun and interesting for attendees but probably has limited educational or intellectual value.

One must acknowledge this lack of shared terminology could be significant threat to this study’s validity - only observed in hindsight - and is related to a possible lack of clearly shared definitions in the interview-based, second phase of the study. In interpreting the interview results, it seems that if the interviewers said, “active learning,” then it is possible that interviewees could have been translating that phrase to be synonymous with some vague notion of “interactivity”. Closely related to this is that the very presentation goals of the planetarium educators in the first place could be a threat to this study - if the planetarium educators have no desire to teach the attendees anything, but merely to entertain and inspire audiences, then active learning in and of itself might be counterproductive and as such an undesirable presentation technique to which the planetarium educators would knowingly and purposefully abstain. Both of these seem rather unlikely to dramatically impact the study results, and it is unclear if presenters could knowingly and purposefully abstain from active learning entirely.

Overall, study-participants consistently expressed what seemed to be a sincere desire to improve and expand their active learning and interactivity strategies, however they feel inhibited in a few different ways. The main barrier they universally expressed was simply a lack of exposure to and training in different interactive teaching styles and experience with implementing active learning. One participant stated: “I don’t know what I don’t know”, implying she is not aware of other forms of active learning and she would consider implementing new approaches if she knew them. This result is entirely consistent with work reported by Slater (2020, p. 804) showing that university-level astronomy professors have a vague feeling that lecturing is not the best approach to teaching astronomy to non-scientists but are at a complete loss of what else they might do.

The core methodological question of any study of this nature is, "is the sample of participants representative of the larger body of planetarium educators?" We believe this sample is representative. When comparing our sample to those reported, and described in detail earlier, to samples used by Plummer and Small (2013) and by Schultz and Slater (2020), it is observed that the participants in this study seem to have the similar demographics as these other studies. This observation can be interpreted as either most planetarium education research studies selectively study the same types of planetarians or that these samples are reasonable subsets mirroring the larger population of planetarium educators. We judge that the later explanation is more likely than the former.

The results of this study point toward a multi-pronged agenda for the discipline-based planetarium education research community. To date, Slater and Tatge (2017) judge that vast majority of "study" has been done in planetariums under the banner of funding in terms of "effectiveness evaluation" and "impact evaluation," neither of which really constitute what science educators would classify as systematic education research (Ball & Forzani, 2007). A fruitful education research pathway that would greatly benefit the planetarium education community is a focus on understanding the specific learning gains that different approaches make in the planetarium through student pre- and post-testing of a diversity of students under various learning conditions. It has been quite some time since a considerable amount of traditional pre- and post-testing of student learning in the planetarium has been published—or perhaps even been rigorously conducted—in the science education literature (Slater, 2017). This is perhaps because it is incredibly difficult to fully comply with human subjects and institutional review board guidelines in a planetarium environment. Alternatively, the lack of publication of such results could be due to the lack of appropriate measures of learning, such as the TOAST *Test Of Astronomy STandards* (Slater, 2014) just do not readily apply in the planetarium environment. Or, perhaps simply that a 45-minute learning experience in the planetarium isn't life changing in either cognitive or affective domains. Nonetheless, it isn't being done and with modern tools and approaches to educational research, understanding what changes, if any, are happening during a planetarium learning experience would be of great benefit to the planetarium education community, and the broader science education scholarly literature base.

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