AUTHENTIC SCIENCE EXPERIENCES: PRE-COLLEGIATE SCIENCE EDUCATORS' SUCCESSES AND CHALLENGES DURING PROFESSIONAL DEVELOPMENT

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Abstract

Twenty-three pre-collegiate educators of elementary students (ages 5-10 years) and secondary students (ages 11-18 years) attended a two-week science, technology, engineering, and mathematics (STEM) astronomy focused professional development in the summer of 2015 with activities focused on authentic science experiences, inquiry, and partnership building. 'Authentic' in this research refers to scientific skills and are defined. The study explores the authentic science education experience of the pre-collegiate educators, detailing the components of authentic science as seen through a social constructionism lens. Using qualitative and quantitative methods, the researchers analyzed the successes and challenges of pre-collegiate science and mathematics educators when immersed in STEM and astronomy authentic science practices, the educators' perceptions before and after the authentic science practices, and the educators' performance on pre to post content tests during the authentic science practices. Findings show that the educators were initially engaged, then disengaged, and then finally re-engaged with the authentic experience. Qualitative responses are shared, as are the significant results of the quantitative pre to post content learning scores of the educators. Conclusions include the necessity for PD team delivery of detailed explanations to the participants - before, during, and after – for the entire authentic *science experience and partnership building processes. Furthermore, expert structure and support is vital for participant research question generation, data collection, and data analysis (successes, failures, and reattempts). Overall, in order to include authentic science in pre-collegiate classrooms, elementary and secondary educators need experience, instruction, scaffolding, and continued support with the STEM processes.*

Key words: *authentic science, astronomy outreach, inquiry activities, partnership building, professional development, STEM education.*

Introduction

It often requires a leap of faith for educators at all levels to try new strategies in their classrooms. For educators, it can be unsettling as well as uncomfortable to motivate and encourage students using means and methods that are unfamiliar. Globally, "science curriculum reform has seen a renewed interest in a number of countries in a greater use of real world contexts in the teaching of science" (Fensham, 2009, p. 884). Similarly, in a time when U.S. pre-collegiate science, technology, engineering, and mathematics (STEM) educators embrace - and post-secondary educators investigate and explore - inquiry and active learning movements (Beichner, 2008), authentic science experiences are paramount for educators and their students. One such authentic science experience occurred during the summer of 2015 when 23 pre-collegiate educators met for two weeks to engage in astronomy activities that directly related to the STEM content that they would teach in the 2015-2016 academic year. This pre-collegiate STEM professional development (PD) was entitled *Launching Astronomy: Standards and STEM Integration* (LASSI). An extension of prior PD experiences (Burrows, 2015), LASSI's team and participants targeted authentic science practices and partnerships, which for most pre-collegiate educators is an atypical classroom construct or endeavor in practice.

Problem of Research

Educators in countries across the world are looking to incorporate real-world scenarios as they teach (Fensham, 2009). "Students need preparation to explore, analyze, and attempt to solve the big societal challenges of today and tomorrow, challenges that are global in nature – including climate change, food and water security, global health, human rights, migration, sustainability, and technological innovation" (Whitehead, 2016, p. 1) In the U.S., pre-collegiate educators (teachers of elementary students aged 5-10 years, and secondary students aged 11-18 years) often ignore the importance of the use of real-world scenarios and authentic science practices in classrooms (Rule, 2006; Sadler, Burgin, McKinney, & Ponjuan, 2010; Yore & Treagust, 2006), although they are called for in the U.S. Next Generation Science Standards – NGSS (NGSS Lead States, 2013). Real-world and authentic science practices include: A) Working toward a solution of a real-world problem, B) Exploring and summarizing current information, C) Using scientific instruments and technology, D) Using appropriate mathematics in the analysis of data, E) Analyzing evidence and using the findings as a basis for conclusions, F) Developing and/or refining questions during the activity and presenting new questions as a result of the work, G) Developing and/or refining procedures and methods, H) Communicating the methods used and results of work to peers/colleagues for review and critique and engaging in that process, I) Collaborating with others in meaningful ways throughout the process, and J) Recording the results of their work where it is accessible to the broader scientific community (Spuck, 2014). Crawford (2014) emphasizes the need for authentic science use in classrooms as she states,

> As compared with an inquiry approach that engages students in asking and answering questions, traditional science instruction often asks students to engage in rote memorization and regurgitation of facts. In contrast, inquiry gives students opportunity to grapple with data and construct possible answers. On the one hand, scientists' science is not exactly the same as classroom science in its

> sophistication and use of elaborate equipment, scope, and duration. On the other hand, classroom inquiry can resemble many aspects of a scientist's inquiry. *A reasonable goal of classroom science teachers includes helping students learn how to think in similar ways to that of scientists, do the kinds of work [that] scientists do, and develop insight into tenets of nature of science* [emphasis added] (see NGSS Lead States, 2013). (p. 526)

Thus, the first step to enable educators to use authentic science with their students is to have them immersed in the experience themselves. The LASSI PD incorporated all of these real-world, authentic science components, and emphasized the value of using authentic science practices in elementary though secondary classrooms by engaging educators in an authentic science experience and exposing them to others. This problem motivates the researchers' three questions (next section).

Research Focus: Theoretical Framework and Literature Review

An interpretivist, social constructionism theoretical perspective was embraced during this study (Koro-Ljungberg, Yendol-Hoppey, Smith, & Hayes, 2009). The researchers grappled with describing the group's socially constructed view of the authentic science practice phenomenon, while concentrating on locating and transformation during the process. The aspects of authentic science as defined by Spuck (2014) were integrated into the LASSI experience, while the team and educators addressed the Common Core mathematics and NGSS standards (NGA, 2010; NGSS Lead States, 2013). In order to more fully understand the context of the LASSI PD, the researchers offer a brief literature review on international practices, the U.S. STEM movement and teacher certification, the use of authentic science and inquiry, and a quality professional development system.

By utilizing international assessments such as the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS), the U.S. Common Core (mathematics) standards and NGSS (science) standards share the following international-benchmarking characteristics (NGA, 2010; NGSS Lead States, 2013):

- Integrated science standards (rather than grade-level, subject-specific middle grade courses)
- Physical science standards receive the most emphasis (chemistry and physics content)
- Life science standards focus on human biology and relationships among living things
- Crosscutting content, such as the nature of science, receives considerable attention

The above hallmarks of strong science programs across countries that score well on PISA and TIMSS, resonate in authentic science practices and experiences. In the U.S. the movement for STEM integration includes authentic science practices (Crawford, 2014).

As of 2011-2012, with ~145,000 secondary mathematics educators (where ~66% have a major/minor in the content) and ~127,000 secondary science educators (where ~77% have a major/minor in the content), the large majority of U.S. secondary STEM educators have a degree (major or minor) in the disciplinary field in which they are teaching (Hill & Stearns, 2015). However, these percentages drop with middle school and elementary teachers (Baldi, Warner-Griffin & Tadler, 2015). Thus, secondary educators are more likely to have real-world authentic experiences through their major/minor content. Consequently, many elementary through secondary educators have not experienced research in its pure, evolving form – in the field or laboratory. Indeed, researchers contend, "that laboratory□based school science teaching needs to be complemented by … learning that draws on the actual world" (Braund & Reiss, 2006, p. 1373), and this is authentic science practice. Since authentic science practice is needed in order for the educators to then create lessons and implement those lessons with their own students, PD opportunities are often the only place where educators can obtain this critical practice.

Quality PD stresses the need for several components including: A) Improvement of content knowledge, pedagogy, and dispositions (Crippen, 2012; Loucks-Horsley, Love, Stiles, Mudry & Hewson, 2003; Penuel et al., 2007; Zozakiewicz & Rodriguez, 2007); B) Creation of instructional materials (Burrows, Briener, Keiner, & Behm, 2014; Jackson & Ash, 2012; Stolk, DeJong, Bulte & Pilot, 2011); C) Use of authentic science and inquiry practices (Marshall & Alsont, 2014; Spuck, 2014); D) Consideration of socioscientific issues (Zeidler, 2014); E) Iterative cycles of use and reflection (Penuel et al., 2007); and F) Partnership development (Burrows, 2015). Astronomy and physics PDs, which lend themselves to physical manipulation and modeling, can utilize the aforementioned components and enhance authentic science experiences to spark the imagination of educators (Roth, 2012). Finally, student achievement is influenced by educator expectations (Steele, 2010), and educator expectations are rooted in understanding – like immersion in STEM practices (Burrows, Borowczak, Slater, & Haynes, 2012).

To explore the authentic science components of LASSI, the research questions included:

- How will pre-collegiate STEM educators describe successes and challenges when immersed in astronomy authentic science practices?
- What are the pre-collegiate STEM educators' perceptions before and after astronomy authentic science practices?
- How will pre-collegiate STEM educators show learning gains on pre to post content tests during the astronomy authentic science practices?

Methodology of Research

Professional Development Experiences during LASSI

In order to engage the educators fully in an authentic STEM and astronomy research process, the pre-collegiate educators participated in self-designed research projects (described later in this section) using the techniques, equipment, and expertise of professional astronomers. Throughout the two-week PD, the pre-collegiate educators (elementary and secondary teachers) were engaged with a broad range of astronomy and physics concepts to use in the classroom (all LASSI activities are freely available and can be found on UWpd.org/LASSI) to provide the groundwork and background knowledge necessary to transform them into researchers (Slater, Burrows, French, Sanchez, & Tatge, 2014).

The researchers sent an email to approximately 500 STEM teachers within a 645 km (~400-mile) radius. The researchers accepted twenty-three pre-collegiate educators that then participated in LASSI during the summer of 2015 for two weeks. Thus, the 18 female and five male participants were self-selected. Although all of the educators taught science (n=21) or mathematics (n=2), they taught a variety of grade levels from elementary (n=17) through secondary school (n=6). The LASSI team assigned participants into eight groups of mixed grade-level pre-collegiate educators, who then self-created authentic astronomy questions (during the morning PD) as well as investigated content activities (during the afternoon PD) during the ten summer days.

The pre-collegiate educators were split into two primary groups, each tied to a research facility in Wyoming – the Student Teaching and Research (STAR) telescope and the Wyoming Infra-Red Observatory (WIRO). The researchers provided guiding questions for the participants to direct them in developing their own research directions, if they wanted to use them. These participant research directions (conducted in the mornings) were in addition to a myriad of astronomy related activities and lectures (conducted in the afternoons - such as Stellar Classification, EM spectrum, & Gravity). The starting research questions for the STAR Projects included: A) How do we know the size (radius or diameter) of Jupiter?, B) What are the Galilean Moons?, C) How can we measure the orbital radius (aka semi-major axis) of one of Jupiter's Moons?, D) What causes the resonance between the Galilean Moons?, and E) How can you determine the mass of Jupiter? The beginning research questions of interest for the WIRO Projects included: A) Who were the Harvard Computers, and what science did they do?, B) How do stellar spectra compare to galaxy spectra?, C) How can we tell how far away a galaxy is?, D) What affects the shape of an emission or absorption line?, and E) If you wanted to request time to use WIRO with your students, what would you want to observe and why?

For context, STAR is a Schmidt-Cassegrain telescope with a 16-inch primary mirror, located on the roof of the University of Wyoming Physical Sciences building. It is primarily used for teaching purposes in introductory-level astronomy classes, as well as for public outreach. It has a variety of eyepieces available to provide various levels of magnification for direct viewing. LASSI participants had access to the telescope every evening during the first week of the PD to make observations in pursuit of solving their chosen research question. PD instructors were on hand to provide guidance and technical support during the telescope use. WIRO (Findlay et al., in press) is a research-grade observatory located on Jelm Mountain, about 25 miles west of Laramie, Wyoming at an elevation of 2943.1 m (or 9656 ft.). WIRO has a 2.4 m (~7.9 ft.) primary mirror, and is the largest telescope, owned by a single university, in the United States. Students and faculty alike heavily use it, providing data for the basis of over 100 peer-reviewed publications in astronomical journals to date, on topics from massive stars to distant galaxies. It is equipped with an imaging camera for precise photometric observations, as well as a long-slit spectrograph. The latter instrument was installed for use during the PD. The first halves of three nights (from sunset until approximately midnight) were dedicated to the PD. Each night, a small subset (3-4 participants) of the WIRO pre-collegiate educator group was taken to the telescope, given a tour, and guided through the observing process. Given the sensitive nature of the telescope, and the high degree of technical proficiency needed to operate it properly, expert observers were on hand to perform most tasks. However, educators were able to participate in preparing instruments (such as filling the camera cooling system with liquid nitrogen), and giving commands to the telescope to point at different objects or take exposures of various lengths. As opposed to STAR however, observing targets were selected strategically before the PD, to provide data from a variety of celestial sources. These included bright, low mass stars, galaxies, and quasars. These classes of objects were chosen to provide a range of spectral features for educators to exploit in their research projects.

When doing astronomical research from the ground, the pre-collegiate educators were always at the mercy of the weather. With limited days available to use the telescope, unfortunately several of the dedicated observing nights were cloudy. However, this allowed the team to expose the participants to other techniques also used by professional astronomers – in particular, sharing data with colleagues who were more fortunate with collecting data, and utilizing archival data, particularly from dedicated astronomical surveys.

In the case of the STAR group, given that they were primarily observing planets within the Solar System, they utilized electronic observing tools such as Stellarium. This software can provide, for example, images of Jupiter and the four Galilean moons, at any given date or time. For the WIRO group, the LASSI team specifically selected observing targets that had data available from the Sloan Digital Sky Survey (SDSS) (York et al., 2000). SDSS is one of the largest and most successful astronomy surveys to date, providing images of over one quarter of the entire sky, and spectra of many millions of objects, all of which is available to the public. The PD participants were provided with SDSS spectra of objects when we were not able to obtain high-quality data with WIRO. This also provided the pre-collegiate educators with an introduction to the wealth of data SDSS has available that they may use with their students, as well as the many outreach and education products SDSS provides.

As educators were slowly introduced to various topics (e.g. Foundations of Computing, Gas Giants, Hubble Law, Classification, & Doppler Effect) they periodically engaged in "expert" time during which they were tasked with developing research project ideas while several astronomy experts were available for consultation. The researchers provide here a sample of four projects that groups undertook during the two-week PD. Four are highlighted here, but all eight posters for the pre-collegiate educators can be found at UWpd.org/LASSI/lessons.html.

The Mass of Jupiter (STAR)

Jupiter is the largest planet in the Solar System, and has four moons (known as the Galilean Moons) that are easily viewable with even small telescopes from Earth. Drawing from lessons on gravitation and Kepler's laws, which describe the motion of orbiting bodies, a group planned to deduce the mass of Jupiter by observing the orbits of these moons. Using images from direct observations with STAR along with electronic versions to fill in cloudy nights, the group watched the movement of the moons to deduce their orbital periods (*P*). Assuming the size of Jupiter is known, its apparent diameter through the telescope can be used to set the observational scale and determine the maximum distance of the moon from Jupiter (assumed to be the orbital radius, or more specifically the semi-major axis *a*) of the moon. Using Kepler's third law, which relates the semi-major axis to the period via: $P^2 = a^3$ the mass of Jupiter (in units of the Earth's mass) can be determined. Repeating the measurement for each of the four moons provides independent follow up and an estimate of the measurement uncertainty. This group also explored the idea of orbital resonance, which is established by gravitational interactions between individual objects in many-bodied systems and set fixed ratios between the periods of those objects.

Angular Size and Distance (STAR)

Another set of participants decided to simulate telescopic observations and methods using a camera and various objects. In their experiment, they attempted to determine the true linear size of objects in a photograph, by using known distances and measuring apparent sizes. This was inspired by a question derived from the Mass of Jupiter group, as they used the known size of Jupiter to set the physical scale in telescope images. This experiment set-up is readily accessible and provides a simplified version of the technique, but it can be extended to the telescopes later. The process involves one equation, the relationship between angular size (a, in radians), physical size *L* and distance *D:* a = L/D. First, a camera is placed on a tripod. Then, objects are placed in front of the camera at known distances (measured with a tape measure), and images are captured of each. Then, the same is done for a quarter, which is the "reference image" and the only object for which a direct, linear size *L* is measured (the diameter of the quarter). By calculating the angular size of the quarter, and using the above equation, the angular scale of the photographs is set. This can then be applied to the other objects in the image, rearranging the equation to solve for *L*. This group was successful, and an extra result from this experiment was the finding that deducing *L* for smaller objects was much more difficult than for large objects. This is true in astronomy as well.

Classifying Spectra (WIRO)

Using nine spectra from WIRO (supplemented with data from SDSS), another group attempted to classify the spectra as one of three object types – star, galaxy, or quasar. This relied heavily on what they learned in the classroom activities regarding light. In particular, this relies on principles of blackbody radiation and Kirchoff's laws. The former describes the continuous spectrum of a hot, dense object at a particular temperature *T,* while the latter describe how this radiation is affected when it passes through clouds of gas (i.e. emission and absorption features). In addition, the identification of quasars relies on the Doppler Effect, as gas moving very quickly in the powerful gravitational potential of a black hole will produce very broad emission lines. This group was able to identify three stars, three galaxies, and three quasars in their WIRO data. The stars were clearly much cooler objects, due to the peak of

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their continuum emission lying at very red wavelengths. They also contain strong absorption features, characteristic of the atmosphere of cool stars. The galaxies were identified from their very strong narrow emission lines, characteristic of hot diffuse gas in between stars, heated by the intense radiation of young, newly formed massive stars. Finally, as mentioned above, their broad emission features identified the quasars.

Hubble's Law (WIRO)

In the early 1900's, Edwin Hubble discovered that all galaxies appear to be moving away from us. This ultimately led to the realization that the Universe itself is expanding. One of the WIRO groups attempted to measure the recessional velocities (*v*) of the three galaxies and quasars in the WIRO dataset, by using known emission lines (identified using SDSS information) and their expected wavelength l_0 compared to their measured wavelength l:$v/c=(l-l_0)/ l_0$, where *c* is the speed of light. Because the recessional velocity is caused by the expansion of the Universe, things that are farther away will be moving faster (there is more space to expand between us and the object). Thus, using the current best-measured value for Hubble's constant H_0, the group also could determine a simplified estimate of the distance *d* to each galaxy or quasar: $d=v/H_0$.

During the end of the second week of the PD, each participant group created a poster to showcase the research question, data collected, suggestions/conclusions based on the evidence, and other important information. These posters were disseminated to the LASSI team and other community members at a final poster presentation session. The posters are freely available on the UWpd.org/LASSI website under the 'lesson plan' tab.

Instrument, Procedures, and Data Analysis

In this mixed methods analysis, involving qualitative open responses and quantitative scores, the researchers utilized several data collection methods. A university institutional review board (IRB) assessed and approved this research. Qualitative data sources included: A) Informal interviews, B) Informal journaling in a community notebook, and C) Observational field notes. The informal interviews were held before, during, and after the daily sessions when participants would gather and discuss a topic, and this information was compiled in a LASSI team notebook. The informal journaling community notebook was available all day during each PD session, and there was a page for free open responses and a starter question on the opposite page that was different each day. Participants could add to the community journal at any time during the sessions. The LASSI team observed (e.g. team members walked amongst the PD groups and wrote participants' comments and concerns in notebooks) the setting, participants, and activities before, during, and after sessions both at the university and in the field. Whereas quantitative data sources included: A) Formal survey question responses regarding authentic science, and B) Formal pre/post content assessment scores from individual participants. The formal survey (adapted to say "authentic science" from an agricultural education perception survey using a 9-point scale) was given electronically through an email link, and the formal pre/post content tests (researcher created) were given daily before and after each content session. Additionally, the LASSI team consisted of three physics/astronomy experts, one computer science and engineering expert (all with terminal degrees), two graduate students (with high levels of physics/astronomy content knowledge), and one science education expert to guide the process. Thus, five experts (astronomy Ph. D.s and graduate students) active in astronomy research were an integral part of the LASSI team and participated in participant support as well as the aspects of data collection and analysis.

Coding was used as the main form of qualitative analysis as defined by Creswell (2014). The process included gathering the raw data, organizing and preparing for data analysis, reading and coding the data, dividing the data into themes and descriptions of LASSI, and finally interrelating and interpreting the meaning of the themes and descriptions. By conducting these steps the researchers validated the accuracy of the qualitative information (2014). The researchers ensured the trustworthiness of the data through reliability checks during triangulation measures (Golafshani, 2003). The quantitative data was subjected to descriptive analysis (2014) including the following statistical measures: A) Mean, B) Standard deviation, C) Pearson's Correlation, D) Paired t-test, E) Significance, and F) Effect size - Cohen's d (Sullivan & Feinn, 2012).

Results of Research

Overall, the qualitative data analysis shows that educators want certainty, and are frustrated with ambiguity even when it is a part of the process. The educators called for clear, up-front content knowledge and end-of-project deliverables before the authentic research experience began (Table 1). Additionally, the educators requested less inquiry and open-ended questions/activities/projects and more concrete activities and classroom ready activities, although more inquiry-type activities are called for in the standards. Benefits to the educators included content to take back to classrooms, created lesson plans, and interaction with the experts. While concerns for the educators related to specific project guidance, time management, teaching the content, and using the project information in their classrooms (Table 1). Generally, there was a swing from dissatisfaction with the open-ended research and project, to acceptance of the task with disengagement, but finally engagement and excitement about the authentic science experience along with some participant surprises.

Viewing a typical quote from each major part (beginning, middle, and end) of the PD emphasizes the participants' uneven journey with the process. The following participant quote examples were written in the accessible community notebook. Beginning quotes echoed one participant who on day-3 exclaimed, "I learned (and understand) so much more than I knew before!." The term "like" appears often, as does the use of the exclamation point (!). Middle quotes boomed with uncertainty, such as a participant on day-6 who explained, "I understand the 'inquiry based' approach and the 'authentic research' opportunities, but quite honestly this approach felt disconnect and highly unorganized." Ending quotes were once again optimistic, for example one participant on day-10 boasted, "[I have] an excitement for teaching astronomy concepts in my classroom using STEM integration." More examples of the educators' comments collected during the two PD weeks are included in Table 1, and selected quotes are shown in a progression timeline in Figure 1.

Overall, the quantitative data from the LASSI participants indicates that educators perceive authentic science as a means to more effectively prepare students which matches the ending comments of the participants. Educators believe that teacher preparation programs should include authentic science integration and modeling. Moreover, educators visualize supports (e.g. parental and administrative support), not barriers (e.g. doubts about student capacity), to implementing authentic science (see Table 2) in their classrooms.

Comparing the astronomy/physics content knowledge pre to post scores across all eight tests, the null hypothesis, of no pre to post change, was rejected. The eight pre to post test questions show improvement at a significance level higher than 95% for all questions ($p < .05$), and at a significance level higher than 99.99% for five of the eight questions ($p < .00001$). Importantly, the effect size is large (d ³ 0.8) for all of the eight tests (see Table 3 & Figure 2). The topics included: Foundations of Computing, Galileoscopes, Light/EM Spectrum/Gravity, Doppler Effect, Stellar classification, Galaxies/Quasars/Gas Giants, and Hubble's Law/Remote Observing.

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Table 1. Qualitative samples from 2-week PD showcasing selected quotes from informal interviews, community notebook, and observational field notes for pre-collegiate educators.

Themes	Informal Interviews	Community Notebook	Observational Field Notes
Content knowledge	"I need more of the basics."	"Repeated exposure to pretty much the same concepts – in different ways – day after day helped me finally get a grasp of them."	"I thought over the years that astronomy research had declined or lost emphasis, but this week showed me that the field is quite active and moving forward at a rapid pace."
Project guidance	"More guidance on the project"	"I feel that it would be more beneficial to tell us the project question or expectation on the first day. Why did we create that?"	"Not sure of expectations for the project…somewhat frustrated."
Concrete activities for the PD	"I need more activities."	"I'm used to having the answers – a lot of unknowns is surprising. What do I do?"	"I'd like more classroom ready activities focusing on astronomy."
Classroom support (activities and personnel)	"I would like more ways to specifically take all of this info and apply it to my classroom."	"I have learned a lot of new information but how is it applicable for elementary aged students?"	"I have an excitement now for teaching astronomy concepts in my classroom using STEM integration and projects like this."
Classroom lesson plans	"I can't believe how easy it can be to use STEM in my classroom, and how real experiences can drive my student interest."	"I now have awesome astronomy lessons to use in my physical science class."	"I appreciate the time to make lesson plans."
Expert interaction	"I began to understand things through the help of the experts… and the experiences."	I have learned so much from the experts and really wish we had longer sessions with them. It has inspired me to further my education."	"I love the guest speakers!"
Time Management	"Wow – the time involved to collect data!"	"The first week was hard – knowing what to do and getting enough (or any) data for our STAR project due to weather!"	"What if all the time I'm taking now will be wasted time, and that I will have to pedal faster to fit in 30 hours of work per day next week?"
Surprises	"My sense of 'uncomfortableness' with inquiry-based learning. I haven't had this experience in PDs before."	"The fact that I was able to guess my way to where we were going, but in the end I have much more knowledge because of my research."	"How in-depth I was able to go, and the amount of knowledge I gained without realizing it."

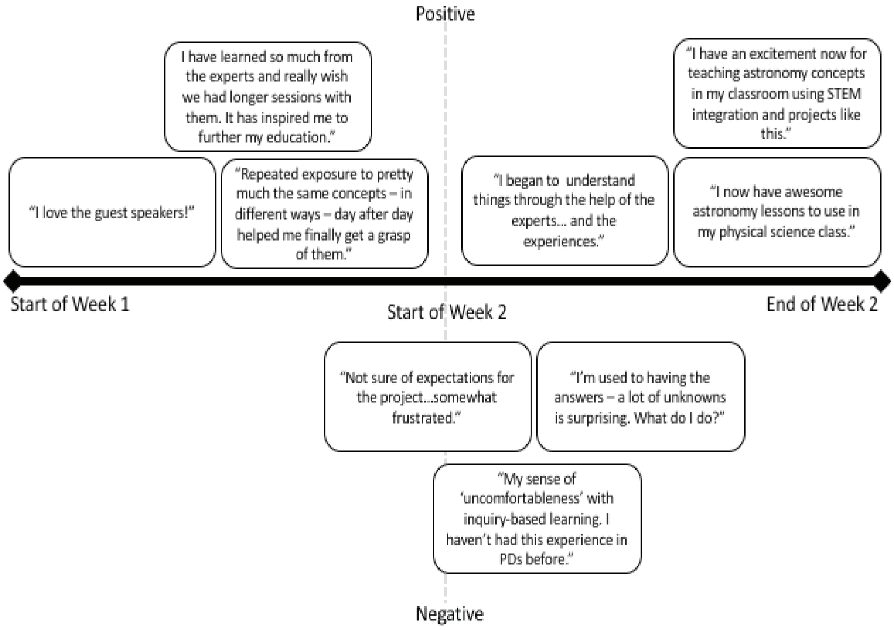

Figure 1: Qualitative samples from 2-week PD showcasing quotes across the engagement spectrum (beginning, middle, and end) for pre-collegiate educators.

Table 2. Quantitative results showcasing ten selected perception questions and responses for pre-collegiate STEM educators [on a 1 (strongly disagree) to 9 (strongly agree) scale].

	Perceptions toward integration of AUTHENTIC SCIENTIFIC INQUIRY		
id	*Question*	*Average*	*Std Dev*
PC1	Students learn more about their courses when authentic scientific inquiry concepts are an integral part of their instruction.	*7. 82*	*1.78*
PC7	Integrating authentic scientific inquiry concepts into a course inceases the ability to teach students to solve problems.	**7.91**	1.30
PC12	Students are better prepared in their courses after they have completed a curriculum that integrates authentic scientific inquiry.	**7.91**	**0.94**
	Preparing to integrate authentic scientific inquiry concepts		
id	*Question*	*Average*	*Std Dev*
TP3	Teacher preparation programs should require students to take more authentic scientific inquiry related courses.	*7.73*	1.27
TP4	Teacher preparation programs should provide instructions on how to integrate authentic scientific inquiry concepts/principles in courses.	**8.18**	**0.87**
TP5	Teacher preparation programs should expect cooperating mentor teachers to model authentic scientific inquiry integration.	7.55	*1.37*
	Barriers to integrate authentic scientific inquiry concepts		
id	*Question*	*Average*	*Std Dev*
B2	Lack of experience in authentic scientific inquiry	5.91	2.17
B6	Concerns about large class size	5.82	*2.60*
B7	Insufficient time and support to plan for implementation	**6.27**	2.15
B9	Disagreement with the notion that authentic scientific inquiry is necessary	*2.36*	**1.21**

Note: Bold numbers indicate 'best' of the category while italics are the 'worst' of the category.

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Table 3. Quantitative results showcasing significance level and effect size regarding pre to post content test scores for pre-collegiate educators during two-week authentic science experience.

Topic	Pre-Test Mean	Pre-Test Std. Dev	Post-Test Mean	Post-Test Std. Dev	N	Pearson's Correla-tion	Paired T	p	Effect Size
Foundation of Computing	2.45	1.96	8.7	0.92	20	0.14	13.64	<0.00001	4.008
Galileoscopes	4.95	1.85	6.5	2.21	20	-0.06	2.34	0.0304	0.76
Light, EM Spectrum, Gravity	5.2	3.19	8.65	2.91	20	0.56	5.4	<0.00001	1.13
Doppler Effect	5.81	2.94	8.71	3.08	21	0.08	3.26	0.0039	0.96
Stellar Clas-sification	4	1.19	6.64	2.48	22	0.3053	5.15	<0.00001	1.29
Galaxies, Quasars, Gas Giants	3	1.72	4.73	1.55	22	0.5369	5.13	<0.00001	1.05
Hubble Law, Remote Observ-ing	3.14	2.39	5.71	2.24	21	0.61	5.78	<0.00001	1.11

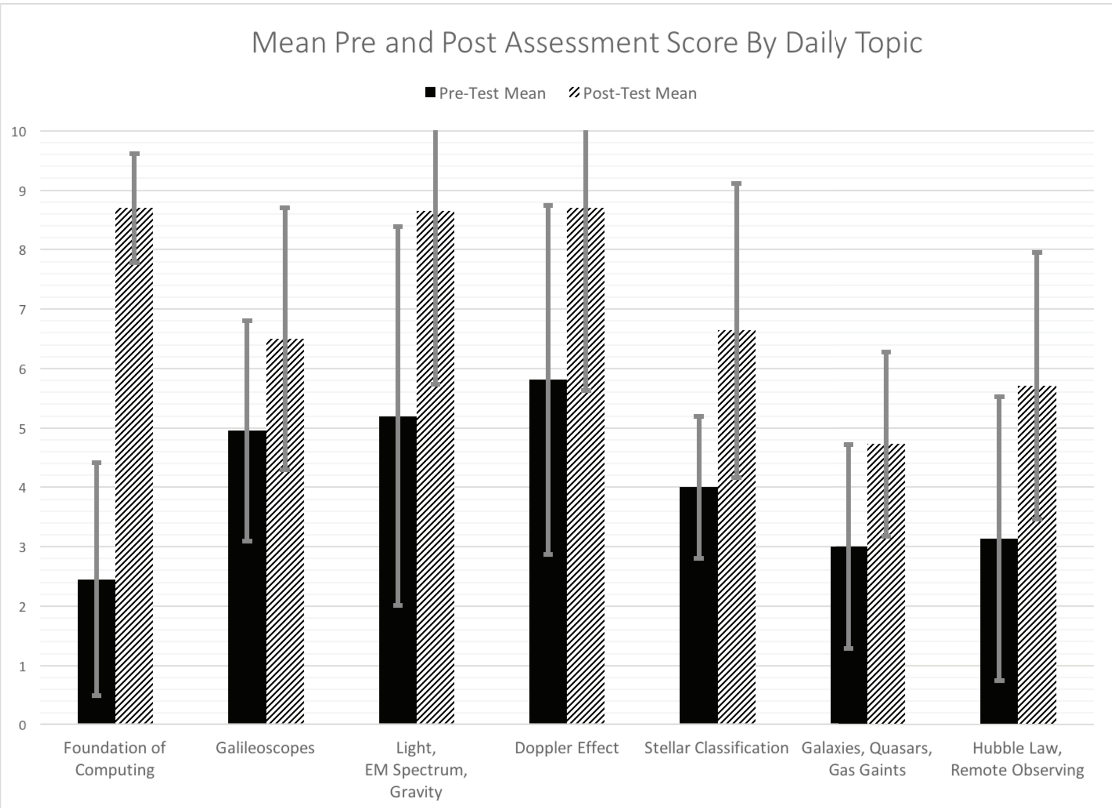

Figure 2: Comparison of pre to post content test scores [on a 1 (low) to 10 (high) scale] for pre-collegiate educators during two-week authentic science experience.

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Limitations

The participant sample for this study was limited with 23 self-selected participants, not purposefully or randomly selected, and thus evaluating a group with similar perspectives and/or motivations might skew the results. The majority of the participant pool consisted of elementary educators (74%) not usually accustomed to research based STEM classes and/or activities/ projects. The project duration of two-weeks, although desirable for a PD, was short for a large research based STEM project. The STEM content focused almost exclusively on astronomy and further studies may be required to generalize these results to other disciplinary PDs. The PD experts were accustomed to educational outreach, and consequently the partnership support was extremely effective and usurped the research project in many areas.

Discussion

Based on the current literature, across the world pre-collegiate STEM educators are striving to incorporate real-world scenarios and authentic scientific practices into their teaching. This research adds clarification to the steps needed in order to engage STEM pre-collegiate educators in authentic science practices. Since the results show that the LASSI educators were initially engaged and excited at the start of the project, then disengaged during the middle, and finally re-engaged in the last few days with the authentic experience, it is vital to guide participants with clear scaffolding in objectives, process, outcomes, and support (written and verbal forms). For some educators, disengagement during the middle (when confusion tends to set in) might seem undesirable, however, the LASSI team found that persistence genuinely produced a more worthwhile experience for the participants. It is apparent that those involved with PDs look for and react to the tension between educators wanting certainty and the fact that authentic science activities are inherently ambiguous. Importantly, the experience of an authentic science PD alone is not sufficient for educators to translate the content and practices learned into realized pedagogy. At the intersection of inquiry activity confusion and useful classroom practice, a PD team can purposefully guide participants through the stages of authentic science acceptance in order to engage the participants with the STEM practices and show meaningful connections to the classroom. The LASSI team undoubtedly embraced this philosophy and challenge other coordinators to do the same.

The participant challenges during LASSI's authentic science experience were polarizing and explicit, and a PD team can learn from these fluctuations. The community journal showcased these extremes of confusion and clarity during the participants' journey through the entire process – from question creation to community dissemination. The participants used the community journal as an anonymous feedback mechanism for the LASSI team as well as a safe forum for expressing doubts and concerns. The LASSI team was pleasantly surprised by the utility of the journal and the richness of the honest reactions in the participant explanations. The PD team met daily to discuss the entries and would begin the next day's session based on the emergent themes identified. The researchers argue that such a journal, anonymous in nature, is needed for continuous and honest participant input.

The partnership building support – such as experts - in place for research question generation, data collection, and data analysis (both failure and reattempts) was crucial. Remember that the LASSI team consisted of three physics/astronomy experts, one computer science and engineering expert all with terminal degrees, two graduate students with high levels of physics/astronomy content knowledge, and one science education expert to guide the process. The breadth of knowledge shared within the LASSI team formed a well-balanced and effective network of professionals that were available to provide participant support during their authentic science experience – especially when the participants were uncertain about the roadblocks over the two-weeks (e.g. weather conditions preventing data collection, reinventing new research questions, defining a data set to answer the research question, synthesizing data

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for community poster dissemination). When creating a PD team, the group needs to not only be well versed in their content but also vested in communication and process reiteration on a regular basis with the participants.

Conclusions

This research is significant as it addresses the vital components required in order to engage STEM pre-collegiate educators in authentic science practices and STEM skills. The PD team must plan for and include participants in clear communication plans, anticipating the stages of inquiry and authentic science engagement, and guide the participants through the excitement of the beginning, "dip" in creating and investigating in the middle, and understanding of the entire process and product at the end. Thus, when creating a PD, a content knowledgeable team needs to explicitly communicate the process – both participant successes and challenges along the way - on a regular basis with the participants and engage them in discussion for the full authentic science and partnership effect to occur. If pre-collegiate educators perceive authentic science as a means to more effectively prepare students (which matches the ending quotes of the participants), then PD teams should provide these experiences as often as possible. Providing authentic science experiences and STEM skill practice extends to teacher preparation programs as well as in-service teacher PDs.

Future studies could include larger participant samples with authentic science educator PDs, especially those that diversify the research topics. Science educators at the collegiate level should consider authentic science experiences for pre-service educators to either start or continue their engagement with scientific practices in their future classrooms. Explorations of participant disengagement during the middle of the process could benefit the STEM PD community as a whole. Methods and means of creating well-defined, shorter (such as this two-week experience) authentic science experiences – with a variety of experts - that can be shared with other educators at all levels could be foundational in building meaningful experiences for future educational authentic science and STEM skill PDs.

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