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The First Big Wave of Astronomy Education Research Dissertations and Some Directions for Future Research Efforts

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Abstract

The past several years have presented the astronomy education research community with a host of foundational research dissertations in the teaching and learning of astronomy. These PhD candidates have been studying the impact of instructional innovations on student learning and systematically validating astronomy learning assessment instruments, both of which are important foundational work for the astronomy education research community. These efforts provide substantial weight to an argument that astronomy education research is maturing into a substantial disciplinary research field with many rich questions to pursue in the future.

1. INTRODUCTION

Systematic reviews of astronomy education research projects over the last three decades reveal that the questions of teaching and learning in the domain of astronomy have often captured the curiosity of science educators and astronomers (Bailey & Slater 2003). In fact, an invited article appearing as "Resource Letter AER-1," written by Bailey and Slater (2005) for the *American Journal of Physics,* describes 135 research articles directly related to a systematic analysis of astronomy teaching and learning; the total literature base on astronomy teaching strategies is, of course, at least 10 times larger. A total of 135 research articles is simultaneously an impressively large number for a disconnected community of researchers to have produced, and a small enough number that one can, with some time, wrap one’s head around and successfully understand the range and domain of ideas, methods, and results. In recent years, astronomy education scholars interested in keeping tabs on the growing literature in astronomy education across numerous journals have volunteered to create various online systems to help, including SABER (Bruning, Bailey, & Brissenden 2007) and ComPADRE (Deustua 2004). However, the premier vehicle for documenting and disseminating research on teaching and learning of astronomy is the *Astronomy Education Review* (Fraknoi & Wolff 2007). In its annual roundups, it too keeps track of the literature published elsewhere (Fraknoi 2006, 2007). In combination, these efforts clearly signal that astronomy education research is a healthily growing discipline in and of itself. But, perhaps even more important, recent months have witnessed an even more impressive nativity—the successful defense of at least nine well-publicized PhD dissertations in astronomy education research. The aim of this article is to briefly summarize the work reported in these dissertations and call the community's attention to this new round of research results. At the conclusion, I suggest some directions for future investigation.

2. DESCRIPTIONS OF DISSERTATION PROJECTS

A large cadre of researchers who systematically study the teaching and learning of astronomy is an important component in ensuring that astronomy education continues to be a rapidly growing and vibrant community. Although somewhat lagging behind the physics education research literature both in duration and in size, astronomy education research is a scholarly research discipline formally and enthusiastically supported by the American Astronomical Society (AAS), the American Physical Society (APS), the Astronomical Society of the Pacific (ASP), and the American Association of Physics Teachers (AAPT) (see http://www.aas.org/governance/resolutions.php#edresearch). In an effort to document this important time in the history of astronomy education research, following are abridged descriptions of scholarly works by students who have earned their doctoral degree—all of which are PhDs in this instance—by studying important problems in the teaching and learning of astronomy.

Janelle M. Bailey's (2006) PhD dissertation at the University of Arizona, through the College of Education's Department of Teaching and Teacher Education, was on the development of a concept inventory to assess students' understanding of, and reasoning difficulties about, the properties and formation of stars. Her study was designed to investigate the beliefs about stars that students hold when they enter an introductory astronomy course, and she used this information to develop a concept inventory that can be used to assess those beliefs pre- and postinstruction. This work is critical because a constructivist approach to instruction requires instructors to first assess students' incoming knowledge and plan instruction accordingly.

She first used student-supplied-response (SSR) surveys to ask more than 2,200 students to write a description of their ideas about topics such as what a star is, how starlight is created, how stars are formed, whether all stars are the same, and more. Looking for trends in the data, she showed that although nearly 80% of undergraduate non-science-majoring students responded in ways suggesting that they knew that stars are made of gas, somewhere between one-third and one-half of the students believed that starlight is created as a result of the star being on fire. Nuclear fusion, the actual energy source in stars, was listed either by name or by inference by fewer than 10% of the students. Interviews with students confirmed that the written responses seen on the SSR surveys were consistent with verbal explanations, lending weight to the reliability and validity of her approach.

In response, she designed and validated an easy-to-use and easy-to-score multiple-choice style instrument, based on students' earlier written responses, that she called the Star Properties Concept Inventory. After several iterations to improve the item response difficulties and discrimination levels, she used results from approximately 500 students to show that those students in an introductory astronomy course for non–science majors increased their scores significantly over the semester, whereas a nontreatment (control) group of students in an introductory earth science course for non–science majors showed no increase. As such, she was able to demonstrate that the developed instrument had sufficient sensitivity to be used to measure the impact of instruction on student understanding of the concepts of stars and star formation. This is an important tool for instructors who want to measure student gains when teaching introductory courses that focus on stars (and galaxies) rather than comprehensive survey courses.

Whereas Janelle Bailey's PhD dissertation was housed in the College of Education's Teaching and Teacher Education Department at the University of Arizona, John Keller's (2006) PhD dissertation took a very different route. Keller was a PhD student at the University of Arizona in the Department of Planetary Science in the College of Sciences. His dissertation and oral defense had two distinct portions. One half was conventional science research, which described his work on the distribution of chlorine on Mars measured by the Mars Odyssey Gamma Ray Spectrometer (GRS), and the other half focused on astronomy education research. This second half, focused on the teaching and learning of astronomy, involved developing and validatating a concept inventory addressing students' beliefs and reasoning difficulties regarding the greenhouse effect.

Keller used an approach similar to Bailey's to determine the range and domain of student beliefs and reasoning difficulties associated with the greenhouse effect. He used written survey responses from more than 900 undergraduate non–science majors at the University of Arizona and 14 validation interviews. Through several iterations, he was able to develop a multiple-choice-style assessment tool that he named the Greenhouse Effect Concept Inventory (GECI). Somewhat surprisingly, although many authors have tried to systematically look at individuals' understandings of "global warming," none had attempted to uncover and characterize an understanding of individuals' cognitive understandings related to causes and consequences of the enhanced greenhouse effect and solutions to it. In particular, the GECI focuses primarily on the physics of energy flow through the Earth's atmosphere—topics that physical science instruction targets—rather than on broader global warming issues, which typically have much more of an environmental, economic, and natural resources focus.

Keller was able to document that many students have a reasonably correct understanding that carbon dioxide is an important greenhouse gas and that the greenhouse effect increases planetary surface temperatures. Further, he was able to identify that undergraduate non–science majors commonly associate the greenhouse effect with increased penetration of sunlight into, and trapping of solar energy in, the atmosphere. What he found, which was somewhat unexpected, was that students frequently intermingle concepts associated with the greenhouse effect, global warming, and ozone depletion. What appears to be making these ideas difficult for students to grasp is that students also describe inaccurate and incomplete trapping models, which include permanent trapping, trapping through reflection, and trapping of gases and pollution. All these ideas are well poised to interfere with instruction designed to help learners develop correct conceptual models of warming due to the greenhouse effect. This work has resulted in an important assessment tool for instructors who want to measure student gains when teaching introductory courses that focus on planetary science, rather than comprehensive survey courses.

Also working on developing assessment tools to determine students' understanding of a particular area in astronomy, Erin Weeks Bardar (2006) completed her PhD dissertation in Boston University's Department of Astronomy. She focused her work on the development and analysis of spectroscopic learning intervention activities and created the Light and Spectroscopy Concept Inventory (LSCI) for introductory college astronomy. It is widely recognized that the most common topic taught across all of introductory astronomy is the nature of light and the electromagnetic spectrum (Slater et al. 2001). At the same time, the nature of light is one of those topics that so many students struggle to understand. Her goal was to design and validate an instrument with the sensitivity to distinguish the relative effectiveness of various teaching interventions within the context of introductory college astronomy.

Bardar used a systematic approach to determine the range and domain of undergraduate non–science major understandings of light and spectroscopy. This strategy included multiple rounds of clinical interviews, open-ended written surveys, and multiple-choice testing on (1) the concepts of the nature of the electromagnetic spectrum, including the interrelationships of wavelength, frequency, energy, and speed, (2) interpretation of Doppler shift, (3) properties of blackbody radiation, and (4) the connection between spectral features and underlying physical processes.

She conducted a complex multi-institution field test of the LSCI with students from 14 course sections across 11 colleges and universities that employed various instructional techniques. She was able to illustrate statistically significant learning gains across sections in which light and spectroscopy were addressed and further showed that courses that heavily target light and spectroscopy using a specially designed curriculum had the highest gains. Of all the new instruments available to astronomy education researchers, the LSCI is probably being used the most extensively to systematically compare different instructional strategies and curriculum materials—perhaps even surpassing the use of the ubiquitously cited Astronomy Diagnostic Test (Brogt et al. 2007). The LSCI's main strength is that it delves deeply into a single topic, giving it considerable sensitivity to detect different classroom contexts. On the other hand, this is also a potential weakness in that its items are so detailed, it might not tightly align with many instructors' opinions about the depth to which non-science-majoring students should understand the nature of light and spectroscopy.

In contrast to the careful creation and validation of conceptual inventories, another group of dissertations has been looking at student learning in the context of innovative curriculum approaches and instructional strategies. David Hudgins, an astronomy professor at Rockhust University in Missouri who works in a very long distance science education PhD program through the University of South Africa, studied the effectiveness of collaborative "ranking tasks" on student understanding across several key astronomy concepts. Ranking tasks exist at a unique intersection of qualitative understanding and qualitative reasoning. As a somewhat simplistic but illustrative example, students involved in a ranking task might be asked to list the planets of our Solar System, from greatest to least amount of time to orbit our Sun.

Hudgins performed a single-group repeated measures experiment across eight key introductory astronomy topics with 253 students at the University of Arizona. Student understanding of these astronomy topics was assessed before and after traditional instruction in an introductory astronomy course. Then, after a pre-to-post measurement of student understanding as a result of lecture had been conducted, the course instructors implemented collaborative ranking tasks, and student understanding was evaluated again at the end of each topic. Average scores on multiple-choice tests specially designed for this study across the eight astronomy topics increased from 32% before instruction to 61% after traditional instruction, and up to 77% after the ranking-task exercises. A Likert scale attitude survey found that 83% of the students participating in the 16-week study believed that the ranking-task exercises increased their understanding of core astronomy concepts. This work is paving the way for a concerted effort among curriculum developers to create collaborative ranking-task exercises and derivative types of exercises that collectively aim to improve student understanding across many astronomy topics.

Simultaneously, at the University of Toronto, Nalini Chandra (2006) was defending her PhD dissertation in the Ontario Institute for Studies in Education on a more traditionally challenging topic, students' misconceptions regarding seasons, but in the context of computer-aided instruction. She conducted three investigations, all building on the previous ones, to explore the question of how geocentric versus heliocentric frames of reference influence students' conceptual understanding of seasons. She approached this question using three ways of representing Earth and Sun relationships based on the representations from Starry Night(TM) software, 3D models, and textbook diagrams. She found that some single frames of reference can limit students' understanding of seasons or confuse students, whereas additional frames of reference can enhance students' understanding.

She went on to carefully observe how 16 sixth-grade students' explanations about seasons changed as they were exposed to different frames of reference over the course of seven days for two hours per day. She found that students' explanations of seasons changed gradually and incorporated their experiences as they were introduced to new frames of reference. She then explored what was happening to the students' intuitive understanding of seasons as they moved between different frames of reference in a problem-solving situation. Qualitative discourse analysis from three student pairs revealed that as students moved between different frames of reference, they brought vastly different types of knowledge (or mental resources) to bear on their initial ideas about seasons. In the end, she concluded that using a variety of frames of reference to teach students about seasons helps learners relate to the topic in multiple ways to foster deeper understanding of seasons. This lends weight to a heretofore unexamined assumption that students need repeated exposure to an idea from many angles to master a concept.

Also during this time period, research questions about how technology can enhance student learning were being pursued as an important component of the teaching and learning of astronomy. Julia Plummer (2006), working on her PhD dissertation in the University of Michigan School of Education, systematically looked at students' development of astronomy concepts across time. Her distinguished work was awarded the 2007 National Association of Research in Science Teaching's Outstanding Dissertation Award. She focused on describing children's knowledge of apparent celestial motion through elementary and middle school, exploring early elementary students' ability to learn these topics when taught in a planetarium. Her work provides an important step toward an understanding of students' "learning progressions," which could provide important iterations in determining the most efficient strategies for instruction.

First, 60 students in third and eighth grades were interviewed in a planetarium setting that allowed the students to use a wide variety of modalities to demonstrate their ideas using an artificial sky. Analysis of these interviews confirmed a generally accepted notion among planetarium educators that students do not naturally make the types of sky observations necessary to learn apparent celestial motion, nor has any instruction they may have received in the past been sufficient to help students acquire an accurate understanding of sky motions. In response, Plummer used kinesthetic-style instructional strategies in a planetarium program designed to improve students' understandings of celestial motion. Pre- and postinterviews were conducted with 63 students from first and second grades who demonstrated significant improvement in all conceptual areas of apparent celestial motion covered by the planetarium program. Moreover, many of the students surpassed the preexisting middle school students' understanding of these concepts. Her results suggest that there could be great value in kinesthetic-style instructional approaches, particularly in a planetarium environment, for improving understanding of celestial motion. Her work adds specificity to the notion that active learners achieve greater learning gains than passive learners.

Pushing new strategies in computer-aided instructional approaches, Julia Olsen (2007), finishing her PhD in the Department of Teaching and Teacher Education at the University of Arizona, studied the impacts of computer-based differentiated instruction on special needs students in the context of an activity-based middle school science instructional unit. Olsen specifically wanted to determine if she could use computer-based information delivery to support the learning of special needs students if the information conformed to best known practices in teaching science to these students.

Capitalizing on a unique opportunity to participate in the infrastructure afforded by a nationwide field test of space science curriculum from the Lawrence Hall of Science's Great Explorations in Math and Science (GEMS), Olsen designed software modules to mediate instruction in specific problem areas that special needs students, especially those with learning disabilities, face in learning science. She designed a two-group study using middle school students who were classified as receiving special education services but enrolled in regular education science classes, and compared them with students in the same classes who were not identified as receiving special education services. Students in the control classrooms participated in an activity-oriented field test curriculum that was common to all students within a particular class. Students in the modified treatment group received modified instructional activities that were mediated by a computer and used best practices.

Regular education students using a curriculum that was not modified to conform to best practice standards for special needs students showed an 8% average gain from pre- to posttest, whereas special education students showed a dramatically different 7% decrease. On the other hand, regular education students using the curriculum modified using the best practices for working with special needs students averaged a 9% gain from their pretest to posttest scores, whereas special education students averaged a surprisingly similar 7% gain. These gains initially appear to be small, but they are statistically significant and important in a domain of education research that rarely sees improvement at all. In other words, gains in students' pretest to posttest scores were notably higher for the special education students who used computer-mediated instructional approaches designed using best practices. Overall, the major finding of this work is that most special education students demonstrated substantial gains in learning the content using the modified curriculum. Moreover, students using modified curriculum not only increased in the frequency of their responses but also increased in the quality of their responses to a particular prompt. In addition, responses from special education students in the modified curriculum group were consistently within the range of responses found among the general education population, whose scores also increased. This result directly contradicts the tacit notion that a thoughtful pedagogy somehow restricts the learning of typically high-achieving students.

Focusing on using software to help students actually participate in authentic astronomical research, Pebble Richwine (2007), finishing her PhD in the College of Education's Department of Teaching and Teacher Education at the University of Arizona, focused on determining the impact of authentic science inquiry experiences, studying variable stars, on high school students' knowledge and attitudes about science and astronomy, and beliefs regarding the nature of science.

Using a concurrent mixed-methods approach, she determined how students changed their understanding of the nature of science and astronomy research after participating in an extended authentic inquiry-oriented research experience studying variable stars using a specifically designed curriculum guide of her own design, "In the Hunt for Variable Stars." Ninety students used her authentic scientific investigation curriculum module, and their attitudes and knowledge were compared with those of 50 students in a comparable science course who were not provided with an authentic research experience. Across multiple surveys that she developed specifically for this project, she found statistically significant increases for students in the intervention group as compared with the students in the nonintervention group. To further validate her study, she used qualitative approaches to demonstrate that both groups of students initially held naïve ideas about science and astronomy. However, after participation in her intervention, the most dramatic changes were observed in students' understanding of astronomy content. In combination, the data resulting from her study lend considerable weight to the claim that students will learn more scientifically accurate knowledge of astronomy after participating in authentic inquiry experiences.

Most recently, in February 2008, Larry Krumenaker defended his PhD dissertation in the Department of Science Education at the University of Georgia. His work repeated parts of Philip Sadler's 1986 effort—looking for how the teaching of astronomy at the high school level (students 14–18 years old) has changed. He found that there are nearly 2,500 high schools teaching about 4,000 high school astronomy class sections, with about 20% of all classes having 10 or fewer students. This represents 12%–13% of all U.S. high schools and is consistent with Sadler's results 22 years earlier. Further, classes generally reflect racial, gender, and ethnic demographics of their schools and the nation.

A somewhat unexpected finding was that high schools that offer astronomy courses are more likely to achieve the somewhat illusive No Child Left Behind Annual Yearly Progress (AYP) rankings. Fifteen percent of teachers have never had a college or university course. Overall, his results strongly suggest that astronomy is still an important offering in many high schools and that a large fraction of teachers stand to benefit from professional development opportunities, judging from the small number who have had any undergraduate astronomy courses.

3. SOME OUTSTANDING QUESTIONS

Although the primary goal of this article is to highlight in a single document the important work done in recent months in service to understanding the teaching and learning of astronomy and grounding astronomy education research, it seems appropriate to provide hints to some (but certainly not all) of the outstanding problems that researchers are struggling with in the domain of astronomy education research.

3.1 Scaffolded Learning Progressions

Recent projects have shown that instructional and assessment innovations can have significant impacts on the depth of student learning. These include, but are not limited to, Peer Instruction (Green 2003), collaborative group activities (Slater & Adams 2002), case studies (Herreid 2005), tutorials (Prather et al. 2004), ranking tasks (Hudgins et al. 2006), sorting tasks (Slater, Loranz, & Prather 2007), and role playing (Francis 2005), among many others. However, it is unclear which exact sequences or durations of homework tasks and formative assessments lead to the most valued levels of student understanding. A cursory survey of the literature on teaching innovations suggests that "more different strategies are better," which is most likely untrue because there should be a point of diminishing returns. Some faculty have so many different learning activities and modes that they need to publish a weekly course roadmap for students to follow; these students struggle to "learn how to learn" in the overwhelming number of different modes and often fail to achieve like we would hope. Because the amount of time that students can (or will) devote to learning astronomy is limited, we need to determine just the right combination and length of engagements that will result in the most optimal learning gains, and how this combination varies by student demographics.

3.2 Untested Technological Solutions

Undoubtedly, the future of educational innovations will emphasize interactive technologies. Whether we are talking about personal response devices (a.k.a. "clickers"), computer-based tutors who give rapid formative feedback, or interactive applications for smart cell phones, none of these has been systematically tested and retested in astronomy (cf. Duncan 2005). But the future of effective education doesn't lie with specific technologies; rather, it lies with an underlying philosophy of intellectual engagement. Which underlying and specific instructional approaches can be shown to work equally well across all emerging technologies, including WebCT, Blackboard, Second Life, Flash Simulations, cell phone applications, and so on, regardless of the specifics of the platform? What characteristics of a particular concept require human intervention, and which are sufficiently engaged virtually? In a similar way, what is the benefit of students actually looking through an eyepiece versus data mining through an Internet interface? Further, what are the most valuable characteristics of a course management system, such as astronomica.org, and which characteristics are just distracting "bling"?

3.3 Simulations

In just the last five years, emerging technology has put amazing computational power within the reach of nearly everyone in a formal learning environment. Flash animations can take the power of amazingly tedious and extensive calculations and allow dramatic manipulation simply by moving an online slider bar (Lee, Seidell, & Davis 2007; Slater & Lee 2006). At the extreme, one could imagine a debate about the relative utility of asking students to have an experience of peering at Saturn through a small telescope, as opposed to asking students to conduct original and publishable research on asteroid rotations through new online databases. Simulations will definitely get better, but what is the role of a bigger and better simulation on cognitive understanding and on student attitudes toward astronomy and science and general?

3.4 Real Scientific Data

The Internet now provides access to much of the same data that professional scientists use in their day-to-day work. But do students need to manipulate actual authentic scientific data to learn science? Beyond opinion, what is the real cognitive difference between working with simulated data and actual data? The data are available, but what are the benefits and costs of having learners engage with them in terms of improving student achievement?

It is generally accepted that most undergraduate non–science majors taking an astronomy course spend little to no time actually looking through a telescope. However, there is considerable interest in the possibility of Internet-based remote observing for college students. A focus group discussion was held with 42 self-selected participants at the 2007 ASP COSMOS in the Classroom conference at Pomona College on August 4, 2007. Each participant was asked:

i) How are you using remotely controlled telescopes in teaching ASTRO 101?
ii) If you are not using remotely controlled telescopes in teaching ASTRO 101, what do you need in order to start?
iii) If you could do anything you wanted to in teaching ASTRO 101, what would you do with remotely controlled telescopes?
iv) Which remotely controlled telescopes are you aware of that other participants should know about and

use?

Forty of the 42 college-teaching participants were *not* using remotely controlled telescopes in their teaching at the present time but enthusiastically wanted to. By and large, the participants felt that ASTRO 101 students would benefit greatly from having an experience acquiring data, and by making their own images in particular. However, few were able to offer a precise description of what they would ask their students to do if they had access. Overall, the participants were unclear about what possibilities such resources provide, what resources were available, and just what it is that students should be learning from such an experience. Participants overwhelmingly suggested that easy to implement classroom-proven curriculum materials appropriate for undergraduate non–science majors were an important requirement before these busy faculty would be able to include remote observing in their classes. There are a myriad of theoretical and experimental research questions related to what students can learn from engaging in authentic observations.

3.5 Conceptual Assessment Instruments

Several new conceptual diagnostic assessment tools are described in this article. However, there certainly exist many, many more astronomy concepts still open to being explored using as yet undeveloped assessment tools. Which core ideas still need to be covered, if any? Further, all of these tools created to date have a similar flavor. Researchers in the domain of understanding the nature of science have now abandoned multiple-choice items and are moving back to student-supplied-response formats (see Lederman et al. 2002). Does astronomy need to follow suit, or are carefully designed multiple-choice instruments sufficiently able to provide data on students' understanding of astronomy that are just as rich? And, most important, how do we successfully separate out reported high gain scores from instruments that are too tightly aligned with specific curriculum materials that inadvertently train students to answer survey questions correctly, resulting in inappropriately inflated gain scores?

3.6 Virtual Ongoing Professional Development

Professional societies are becoming considerably more engaged in helping their scientific members become more effective in education and outreach activities. Are poster and short oral presentations at meetings, or even journal articles outlining lessons learned or best practices from one astronomer to another sufficient in and of themselves to impact education and outreach activities? Or do individuals who want to have high-impact education and outreach need to participate in hours, or even days, of professional development? Some research in the K–12 domain suggests that a minimum of 40 hours of professional development, plus additional participation in "group study," is required for K–12 teachers to fundamentally change their approaches (Nelson 2007). Is this true for professional scientists and college/university instructors as well? Given the time and expense of long-duration professional development workshops, which aspects, if any, successfully translate to virtual professional development, either through video podcasting or through electronic learning communities? Which characteristics of virtual professional development work for a generation of scientists who were born long before these emerging technologies became commonplace? These are all open questions to which some anecdotal data hint at answers, but the research is still somewhat speculative.

3.7 Pathways to Enter the Professional Astronomical Community

Undergraduate research experiences for science majors have long held an important role in helping students transform into practicing scientists (Slater et al. 2008). Yet, given the typical 10-week summer research experience, are students fully engaged in scientific inquiry in any meaningful way? In other words, an important question is, What are the real differences between having a student play a small role in a larger scientific research program that results in published multiauthor research in a top-tier journal, and, alternatively, having students involved in a nonoriginal but individual research project in which the learners have actually generated the question to study, devised a strategy to collect and analyze data, and reached an evidence-based conclusion that they defend to other members of the astronomical community, even if it is not publishable as novel research? Do demographics such as ethnicity and gender matter in terms of the benefits of being part of the larger scientific enterprise, versus completing an individual, but smaller and unpublishable, research project? The strategies available to scientists and educators to fill the science career pipeline are many in number but relatively few in practice. What about how graduate students and postdocs are initiated into professional science (Pilachowski & Durisen 2002), and should it be one size fits all? Carefully planned astronomy education research investigations could, and should, provide significant insight into how to best prepare the next generation of scientists and how to engage the spirit and confidence of the self-proclaimed nonscientists in the general populace.

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It has been a great professional privilege and a personal pleasure to have the fortune to work with many of these students and their faculty mentoring committees to varying degrees. Further, I am certain that several other recent PhD dissertations in astronomy education have been completed during the recent window without our knowledge, and I sincerely apologize for any omissions made.

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