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Pre-service Physics Teachers and Physics Education Research

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Abstract. Training pre-service teachers requires, among other things, content knowledge, pedagogical skills and pedagogical content knowledge. Teacher preparation programs have little, if any spare time to add more courses/activities to their program. However, I argue in this paper that we, as educators, must enhance the amount of physics education research in our pre-service physics teacher training programs. In this study, I analyze the results of two different types of exposure to physics education research (PER) from two different groups of pre-service physics teachers in our masters of arts and teaching program. The preliminary results show, for example that the PER helped the pre-service teachers increase their understanding of student thought processes while they solved problems. Physics teachers must have this type of ability to be successful in the classroom.

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INTRODUCTION

One challenge in teacher preparation programs is identifying the proper curriculum that will ensure that pre-service teachers are as prepared as possible. They need to know more than content knowledge; they need to know pedagogical content knowledge (PCK) [1]. One solution is offering specially designed courses on how to teach science [2] or to have these students as learning assistants in science courses [3].

Another idea to help pre-service teachers succeed in the classroom is to have them conduct educational research [4]. Few pre-service teachers conduct actual education research. We know the key for our students to learn physics is from physics education research (PER) [5]. This leads to a question on how to train future physics teachers. If pre-service teachers are better prepared by learning PCK or by conducting research, would future physics teachers become better prepared by conducting research in physics education or at least learning about the results of PER?

THEORETICAL FOUNDATION

The question: “How does physics education research affect the teaching abilities of pre-service physics teachers?” is founded on the idea that pre-service teachers who conduct research do better in the classroom [4] by developing key professional skills. One skill necessary for master teachers is the ability to reflect [6-8]. Others are that we want our teachers to be more critical and analytical [9], self-confident [10], self-directed [11] and have the ability to be open-minded and flexible [12]. What is also critical is that teachers expand upon their conceptions of teaching [13]. Finally, teachers need to be able to work together as a collective group [14].

Data shows that pre-service teachers who conduct science content specific research increases their knowledge and enthusiasm for teaching the material [15]. Other research shows an increase in content knowledge and in the development of scientific skills but warns of hesitancy by teachers to bring actual research into their classroom due to time constraints and standardized testing [16]. However, there is little research available to show how pre-service teachers who learn or conduct content specific education based research utilize that experience in the classroom.

SETTING

All of the participants in this study are graduate students who are or were pre-service physics teachers in the Masters of Arts and Teaching (MAT) program at Kennesaw State University (KSU). KSU is a suburban school just northwest of Atlanta, Georgia with a total student enrollment of about 24,000 students. Kennesaw’s MAT program is typically an intensive 14 month program. The students take a combination of upper level content courses as well as a variety of education courses. In the fall, they complete five weeks of student teaching in a middle school and then 15 weeks in a high school the following semester.

All of the students in the MAT program take courses involving education research. However, these courses are generic by design. The students normally do not get exposure to physics education research.

The students in the MAT program fall into one of two categories. The first are recent engineering graduates who decided to switch over to teaching. The second are individuals who are returning from several years in the workplace. These students have decided to switch careers and pursue their plans to take what they have learned and teach. The first cohort of students in the MAT program was the summer of 2008. Physics had only one student; Craig. The following year saw an increase from one to five students: Matthew, Rachel, Jessica, Anon and Keith.

Craig has a very strong undergraduate background in Physics. He started the MAT program directly after completing his undergraduate physics degree. Craig accepted a teaching job where he teaches chemistry and physics after he completed the MAT program.

Anon and Jessica obtained degrees in mechanical engineering a semester before starting the program. Matthew just completed an electrical engineering degree. Keith’s degree is in geology. He worked in construction for many years before substitute teaching and then starting the program. Rachel graduated with a degree in civil engineering and worked for three years.

The cohorts had different exposures to physics education research. Craig participated in conducting a research study which included collection and analysis of data as well as assisting with writing a paper [17]. Craig also needed to read several articles.

The other five learned about physics education research by being paid participants in this study. At the first meeting, each one was individually shown three videos of subjects chosen at random from another study [17]. These videos were shown because they depict problem solving situations similar to what teachers may experience in a classroom. Two videos show novices, the third shows an expert. The goal was to identify at what level the pre-service teachers could differentiate between experts and novices.

The participant looked at a side-by-side video combination. On the left side they had the video of the eye-tracker while on the right side they had the subjects’ workspace. The eye-tracking video had cross-hairs which allowed the participants to see what the video subjects looked at for a deeper analysis in how the student’s solved the problems. The workplace camera allowed them to hear what the subjects said and to see how they solved the problems. The participants also had printouts of the subjects’ work and the list of interview questions. Following the videos, the participants answered questions about the video, education research and PER.

All five subjects met at the same time during the second meeting. This was a four hour workshop and served as an introduction to PER. Participants began the meeting by reading Hake’s [18] paper on interactive lectures. That paper introduced Hestene’s et al Force Concept Inventory [19] article. These two papers highlighted different reasons why authors write papers. Next, the students needed to come up with their own research project based upon three related research questions. As a group, they needed to come up with a strategy to investigate the questions. After the group decided upon a methodology they read the paper [20] which contained those research questions and compared their methodology with the paper’s methodology. At the conclusion of this workshop the participants read three related papers [21-23] as well as the theoretical framework section of reference [17] before they came to the third meeting.

The third and final meeting was a one-on-one interview. The participants viewed two videos: one expert and one novice. In this situation the expert did not have eye-tracking data where as the novice did. This was specifically done to determine how much the eye-tracking helped (or did not help) the participants analyze the data. The five participants analyzed the videos and answered another series of questions about the videos and physics education research.

SUBJECTS RESPONSES

Craig was the student from the first year who helped conduct a research project. Through our discussions it was apparent that the first year of teaching makes it very difficult to do much more than to keep your head above water. Between coaching, preparing for the first year and implementing new activities, Craig did not conduct any type of research for his own benefit in his own classroom.

Craig shared his research experience with his students and helped them learn to develop traits matching those of experts. Craig gave special attention to address problem spots that he witnessed as a result of his research experience. One example is the confusion students have differentiating between voltage and current. The research helped Craig get an in-depth look into students’ knowledge and how the various tools [24] could be used to augment their understanding of electrical circuits.

The second cohort of pre-service teachers showed improvement in their analysis of student's solutions. Their views on research also greatly changed.

Matthew's initial analysis of the videos was only what the subjects wrote down. For example, the expert used representations but the novice did not. He noticed differences in the thought processes (the mental steps used to solve a problem) but did not elaborate on them. After the workshop, Matthew identified noted misconceptions from a paper [23] he read. For example he identified the novice's dependence on V=IR. More importantly, it helped him understand their thought processes. "*As a teacher, if I saw my students doing that, I think it probably comes with experience, but when you are watching them solve a problem sometimes you jump to conclusions about why it is they are doing what they are doing and that might be wrong. But I think knowing this gives me a better insight on knowing what they are probably thinking while they are solving the problem.*"

Matthew also noticed how his ideas evolved. While analyzing the first set of interviews, Matthew was focused on "*smaller things like word choice of questions*" and that that particular train of thought "*really distracted me from analyzing this type of stuff* (pointing to research articles)." However, in the second interview, Matthew was able to notice "*really stark differences between experts and novices*" by giving examples of differences in time between the groups and how the novice manipulated the equations.

Matthew noted how the research will help him become a better teacher. First is the direct relevance to what he will be doing in the classroom. He likened this knowledge with a toolbox analogy saying that the results of physics education research are a better tool then what he had before. "*Having the right tool will help you get the job done right quicker and more easily than before. You don't have to waste time doing what has already been done before. Skip the mediocre stuff and go right to what's most effective. This is a really quick way to gather what would take me years in the field to understand.*"

Rachel has some slight difficulties initially noticing differences between the experts and novices since she admitted she was rusty on electronics. She noticed the novices had difficulty identifying what is in series and parallel. She knew that the expert was very quick in solving the problems and could do them in his head. After the workshop she was able to identify a lot of the misconceptions as well as understand why students had trouble determining what is in series and what is parallel. She also paid more attention to the confidence level of the novices. For example, the novice in the second video was very confident in his work. Since the novice used the correct formulas, the answers must be correct. Rachel stated that: "*I didn't pick up on stuff like that before. Before I was watching, I was thinking oh they are making mistakes, and I kinda noticed a pattern in the mistakes but I wasn't thinking about why they were making those mistakes other than they didn't know. They just didn't know the right way to do it. But this* [research] *gave me insight as to the way they were accessing the information*."

Her views on research also changed. Initially, "*education research is focused on how the student learns best. So I view it as what is the best way to present whatever material is being presented in a way they can understand it the best.*" In the end "*it was about how do we most effectively teach students, and while that is still a goal, it's not the central goal, really it's about how do you teach students how to think, how to help them develop their thinking and their logic skills to a variety of problems.*"

Though Jessica was weak in her background on electrical circuits she was able to pick up on some trends between the experts and the novices. For example, the expert looked at the problem and then went on to solve it while the novices were "*fishing around*." She saw that the novices knew the terms but sometimes had problems with the concepts. Like the previous two, the articles helped her the second time to "*learn a lot more about how students work through problems.*" She realized the novices had problems beyond what is in series and parallel, but the idea of what is current with a dependence on Ohm's Law.

Her exposure to physics education research was minimal at best. Jessica viewed education research as "*redundant/obvious.*" Furthermore, there needed to be an experiment for it to be research. The short exposure to physics education research dramatically changed her outlook."*It's more useful than I thought. Some of it actually exposes the thought processes of students, which is something I've been struggling to do inside my own classroom. It's nice to have some general and common processes laid out for me where I can analyze them and think about them, not in front of a classroom full of students where I have several other concerns to deal with. I can anticipate rather than react*."

Anon also identified misconceptions students held such as lower resistance always means higher current. Anon also noticed (like others) that the novices had problems with the math and that they did not redraw the circuits. After the research, he was able to identify more of the thought processes. For example, the novice only knew bits and pieces of information. They had difficulties with adding resistors (the rules governing them) and how current was confused with voltage. The article helped him understand why the student was just using numbers and equations. Furthermore, "*Now I know what type of general mistakes students make. Last week I didn't think they* *were thinking of the circuit as linear, rather they just didn't understand that part of the circuit.*"

Anon's previous experience with education research was limited to just a few articles. One thought permeated from Anon was that he "*Learned from education research that it is very hard to penetrate through their preconceptions. Sometimes we just assumed that if they study this they will understand, if we show the steps, they will know how to solve the problem.*" He was very surprised, even slightly dismayed that even after instruction, students hold onto to their original beliefs. Anon also made an interesting comment about research, it is "*important to share PER with administrators, as they are the only ones who can change a school.*"

Keith is the final subject and he summed up all of the participants' initial views of the novices, "*The first student had some real basic misconceptions but I am not sure why that is*." He noticed the difference between the novices (one has problems with the concept and the other has problems with the math) but he lacked the basic understanding of the student's thought process. He noticed with the eye tracking that if the novices got stuck they would rapidly look back and forth but didn't give a reason why. Keith was also the only one who used anything more than content knowledge when analyzing the videos, i.e. listening to the tones in their voice. He later stated this was beyond the scope. He stated he was interested in the pedagogy behind how they solved it but did not elaborate more.

After the workshop he was able to understand not only that the novice did not fully understand Ohms Law, but also that he has it backwards and does not understand the basic foundations. He was also able to identify the misconceptions from the research articles that the students had in the videos.

Keith dramatically changed his view of research. In terms of general education research he was "*not sure how good it has done. Everything seems to be skewed towards testing. Research is skewing it that way.*" Specifically with physics education there is "*not as much physics education [research] as other sciences, possibly due to the reputation as physics being hard.*" After the workshop, Keith stated how his eyes were opened to the research that was out there. The research cleared up stuff difficulties for him but also provides many resources.

DISCUSSION

All of the subjects described surface differences between the experts and novices such as the novices having difficulty with basic algebra and reliance on equations. However they lacked the ability to understand why the groups solved problems the way they did. The pre-service teachers did not explain what the students were thinking (i.e. why students rely on equations) until after reading the articles in the workshop. This supports the argument that learning about research would help future physics teachers.

The workshop and readings were not enough to fully understand physics education research. The workshop only gave an introduction and knowledge of how they could further learn about research. All of the subjects felt they could not successfully conduct research but they do have the fundamentals such as types of research to conduct and ways to conduct it such as interviews and analysis of student work. They also developed a greater appreciation for physics education research.

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