Promoting Conceptual Change Through Course Design: Supporting the Physics CK and PCK Development of Pre-Service Teachers

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Abstract

The focus of this paper is the development of a unique physics course at Georgia State University to produce pre-service secondary science teachers who have the capability of facilitating deep conceptual understanding in high-school physics students – a course which has been developed through the true collaborative efforts of faculty from the College of Arts & Sciences and from the College of Education, and which gives appropriately-apportioned attention to both physics content and physics pedagogy. A brief overview of the development process of the course is be highlighted starting as an ad hoc effort of 'guest lectures' in a physics class highlighting the research promoting conceptual to its current form as a formalized course that purposefully weaves together the physics content with the discussion of models of teaching for conceptual change. The unique curriculum incorporated which purposefully focuses on the concept acquisition of the physics principles of mechanics, heat transfer, and waves within the context of conceptual change teaching strategies [e.g. Clement's (1993) work on bridging analogies, diSessa's (1993) p-prims model and Slotta's and Chi's (2006) ontological misclassification framework] will be presented. In addition, the nature of the collaboration behind the physics and science education faculty is detailed highlighting the conceptual change occurring through the process. This overview of the course is presented as the groundwork for a proposed study to examine the initial implementation of the course this summer.

Introduction

Like many states, Georgia continues to experience a shortage of qualified physics teachers (Henson, 2008). In response to this situation, the GSU MAT program in secondary science has tried to work with the Department of Astronomy & Physics to develop courses which could be taken within the broadfield certification option and would give candidates a strong foundation in physics to those lacking the requisite conceptual background. In 2011, the Department of Physics & Astronomy began the development of a two-course sequence designed to meet the needs of these students. The first of the two courses was piloted in the summer of 2011, and then revised during the academic year through a collaboration with science education faculty from the COE. The current version of the course (scheduled for Summer 2012) will weave together similar content as found in the pilot course with a thorough exploration of strategies for teaching and learning physics to promote conceptual change. This study seeks to examine is the capacity of this revised course design to prepare future science teachers equipped to teach physics in a manner aligned with suggestions made in the national standards documents and conceptual change literature (American Association for the Advancement of Science, 1993; National Research Council, 1996; Vosniadou, 2008).

Research Design

The goal of this project is to study the initial implementation of a unique physics course designed for teacher candidates in the MAT secondary science program and to support the further development of the course. Currently, the candidates in the program are required to have completed 15 credits in physics to meet the broadfield certification requirement. For candidates with no prior college-level physics coursework, eight of those credits can be met through taking the PHYS 7111 / 7112 sequence wherein they enroll in the same sections as undergraduate students (in PHYS 1111 / 1112) and then complete additional work such as serving as tutors or teaching mini-lessons in these classes. For those who already had taken the standard two-course general physics sequence or for those who had completed the PHYS 7111 / 7112 combination, the next options available *had been* PHYS 7450 (Physics for Secondary School Teachers) and PHYS 7910 (Directed Study in Physics). The nature of those two courses were that those enrolled would participate in physics education research projects, function as teaching assistants for PHYS 7111 / 7112, and read material related to physics pedagogy such as Mazur's *Peer Instruction* (1996). While such a flexible set of learning experiences could be meaningfully designed for each individual when the number of candidates requiring the second set of courses was small, an increase in demand by the MAT secondary science candidates in recent years made this model untenable.

The response to this situation was the development of a new two-course sequence (PHYS 7210 / 7220) in the spring of 2011, with the first of the two courses being offered that summer. The idea of this sequence was to create classes, which would only be populated by the MAT secondary science candidates, so that the content (which would mirror that covered in PHYS 7111 / 7112) could be better tailored to fit their career trajectory as future high-school science teachers. As a result of this vision, during the implementation of the pilot version of PHYS 7210 (which focuses on principles of mechanics, heat, and waves), the physics faculty invited a science education faculty member from the College of Education to present a small set of 'guest lectures' which highlighted the research around promoting conceptual change in physics. The success of this ad hoc effort prompted the faculty from the two different colleges to try to develop a new version of the PHYS 7210 course which would purposefully weave together the physics content with the discussion of models of teaching for conceptual change.

In the fall of 2011, the ideas which had emerged as a result of the experience in the summer of 2011 resulted in the development of a course formalizing the integrated physics content – physics pedagogy structure. This course then went through the formal review process and was accepted for incorporation into the physics graduate course catalogue by the appropriate curriculum committees. This modified version of PHYS 7210 is being offered for the first time in the summer of 2012. The course will count for four credits so that sufficient attention can be given to both concept acquisition and discussion / modeling of conceptual change teaching strategies [e.g. Clement's (1993) work on bridging analogies, diSessa's (1993) p-prims model, and Slotta's and Chi's (2006) ontological misclassification framework]. The expectation is that a minimum of 15 MAT secondary science candidates will enroll in the course. These candidates will not only be provided a unique learning experience themselves, but will also get to first observe and then to facilitate the learning of undergraduate students taking the studio version of the introductory physics class (PHYS 1111K). The latter component of the course structure will provide the MAT candidates with the opportunity to use both the content knowledge and pedagogical skills they are developing in order to enhance the active learning of students in the PHYS 1111K summer section (considerable *spillover effects* are expected).

Since the course was developed collaboratively between the faculty in the College of Arts & Sciences (specifically from the Department of Physics & Astronomy) and the faculty from the College of Education, it will be similarly presented in a collaborative manner. While the content delivery of the course will be provided by the physics faculty member, pedagogical issues and challenges related to teaching this content to high school students will be highlighted by the science education faculty member. Similarly, while the science education faculty member will be delivering the content related to conceptual change approaches, the physics faculty member will be able to provide specific contexts to which these ideas might be applied. This collaborative approach will benefit the MAT candidates in terms of the way in which the conceptual change models will help them more effectively construct their knowledge through metacognitive learning strategies (Baird & White, 1996). Further, it is expected that it will offer a benefit to the physics faculty who will become more familiarized with new pedagogical content knowledge (Shulman, 1987). Conversely, the science education faculty should benefit from gains in content knowledge in physics (e.g. through reading materials such as Knight, 2002).

Our rationale for emphasizing conceptual change is that with regard to the content addressed in PHYS 7210, the history of how the concepts evolved within the field of physics is well documented (e.g. Maloney & Siegler, 1993; Matthews, 1994; Minstrell, 1984) and the way these concepts tend to develop (or stagnate) in students is also well known (Taber, 2001). This will make it possible to enrich the content of the course in ways that not using such an overarching teaching model could not. Just as importantly, methods for marshaling the extant knowledge of how ideas related to certain concepts have progressed in the history of science and tend to progress in students often cannot be incorporated into the practices of physics teachers without explicit discussion and modeling of such strategies (Yip, 2001).

In summary, the goal of this project is to examine the initial implementation of a unique physics course (PHYS 7210) at Georgia State University – a course which has been developed through the true collaborative efforts of faculty from the College of Arts & Sciences and from the College of Education, and which gives appropriately-apportioned attention to both physics content and physics pedagogy. With regards to physics pedagogy, the main emphasis will be on conceptual change teaching strategies because we believe these strategies will not only support the concept acquisition and problem-solving efforts of MAT teacher candidates as they take the course, but will benefit their future students as they move either into field experiences or into their own classrooms. Additionally, it is our hypothesis that the collaboration around the design and implementation of this course will increase the knowledge base of the physics and science education faculty involved in terms of their pedagogical and content knowledge respectively. The research efforts surrounding the initial offering of this course will allow those involved to determine the extent to which these outcomes are realized and, if they are, what features of the course structure and enactment most contributed to their attainment. Thus, that research will be able to inform refinements in future iterations of the course to allow it to better achieve the envisioned objectives, as well as offering suggestions for how similar design features might be incorporated into the second course in the sequence (PHYS 7220).

Analytical Metrics

The main goal of the proposed course is producing pre-service secondary science teachers who have the capability of facilitating deep conceptual understanding in high-school physics students. The specific objectives which are encapsulated by this goal are: (1) to increase the conceptual understanding of the pre-service teachers so that they may have the appropriate knowledge base; (2) to heighten the awareness of these teachers regarding the existence and basis (e.g. linguistic, ontological, and epistemological) of physics misconceptions; (3) to foster the formation of the pedagogical content knowledge required to help students bridge the gap between their everyday views of physics-related phenomena and the scientifically-accepted views; and (4) to accomplish the preceding objectives through a collaboration between faculty from two different colleges which will strengthen the knowledge base of each faculty member and can serve as a model for future collaborations around course development and implementation. The research questions which will be explored in order to determine the extent to which those objectives have been met are:

1. What are the differences between pre-service teachers' views of teaching for conceptual change before and after taking the course (PHYS 7210)?
2. How do the interactions between physics and science education faculty contribute to the scientist's understanding of students' misconceptions?
3. Can the newly designed course (PHYS 7210) activities enhance the development of the physicist's and pre-service teachers' self-reflections and metacognitions of teaching and learning? If so, in what ways?
4. To what extent does the course structure and implementation support gains in pre-service teachers' physics knowledge? (Quantitative) What are the features of the course structure and implementation that most significantly contribute to any such gains? (Qualitative)

In order to be able to fully understand *what* changes in both the content and pedagogical knowledge occur in all of the participants (including the faculty teaching the course) as well as *how* and *why* those changes occurred, the research design framing the proposed study will utilize mixed methods over time. Both quantitative (e.g., surveys) and qualitative measures (e.g., student and faculty interviews) will be used to collect data pertinent to answering the research questions shown above. The specific measures comprising the data collection tools with a brief description of each are listed below.

Quantitative Measures:

Concept Inventory Tests: These criterion-referenced tests will be used to evaluate whether a students have an accurate working knowledge of a specific set of physics concepts that PHYS 7210 will emphasize. Concept inventory tests are widely used in physics education research to measure how student learning is affected by implementing specific teaching and learning practices (in this case it will be teaching for conceptual change). During this study several inventory tests which have demonstrated psychometric soundness (such as the ones presented below) will be utilized:

a. *Force Concept Inventory (FCI)* (Hestenes, Wells, & Swackhammer, 1992): A 30 item survey of basic concepts of force in one and two dimensions. A few kinematics questions are included.
b. *Heat and Temperature Concept Evaluation (HTCE)* (Thornton & Sokoloff, 2001): A 28 item survey on concepts of heat, temperature, and heat flow.
c. *Wave Diagnostic Test (WDT)* (Wittmann, 1998): A survey probing student models of mechanical waves on strings and sound. It contains 8 open-response items, each requiring two to three one-sentence answers and 2 multiple-choice multiple-response items.

Qualitative Measures:

1. *Survey*: The survey instrument is designed to elicit pre-service teachers' views on appropriate practices regarding how to respond to students' ideas that are different from those of science. It utilizes a series of open-ended questions that initially focus on general beliefs regarding effective approaches for addressing such ideas and then ends with a specific scenario from an actual physics classroom to provide insight into how those beliefs / approaches would be enacted.
2. *Semi-structured Interview Protocol for Faculty (To be Developed):* This measure will be used to frame individual and/or focus group interviews designed to solicit the science educator and physicist's perspective of collaboration on PHYS 7210 (will be consisted of pre/post interviews).
3. *Semi-structured Interviews for Students (To be Developed):* This measure will be used to frame individual and/or focus group student interviews designed to solicit student perspective of teaching and learning practices (will be consisted of pre/post interviews).
4. *Journaling:* This data source will be used as an additional to examine the effects of conceptual change models of teaching and learning as perceived by faculty and students.

Analysis of Data: The *Concept Inventory Tests* will be subjected to statistical analysis (e.g. t-tests) to determine whether there is significant gain in content knowledge. For our qualitative measures, we will use a variety of methods due to the differing nature of the four data collection tools we will be using, especially given that these tools are designed to provide different types of information related to the research questions. In order to organize and more readily triangulate our data, we will be using NVivo qualitative data analysis software. All the interviews will be transcribed verbatim before this data is entered into NVivo for analysis.

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