How an active-learning class influences physics self-efficacy in pre-service teachers

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Abstract. Education majors in an inquiry-based physics content course were asked to reflect on the ways the course affected their self-efficacy for completing physics tasks, such as creating a circuit. Responses were coded according to the contributor of the influence and whether that influence was positive or negative. The group learning structure, hands-on activities in the class, and the constructed repertoire of science knowledge, processes, and activities, were all reported to be positive influences on self-efficacy, whereas the influence of the instructor was mixed. Overall, students' responses indicated both a desire for more guidance and lecture and an appreciation for their ability to construct their own understanding through the class activities.

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INTRODUCTION

Students entering Physics and Astronomy for Teachers (PAT) often make statements such as "I'm not a scientific thinker," "Science isn't for me," and "I have never been good at science." However, in their future role as teachers, they will be expected to teach physical science content. Kentucky science standards indicate that magnetism, electric circuits, light, force and motion, and moon phases – all covered in PAT – are to be taught in elementary school.

PAT has been a successful approach for teaching physical science concepts [1, 2], which is unsurprising given that it is based on *Physics by Inquiry* [3], which has well-documented achievements [4]. However, to increase pre-service teachers' knowledge of science-related content may be futile without also ensuring that they also feel efficacious in performing science, since self-efficacy provides the motivational incentive to act [5].

Self-efficacy, or a belief in one's capabilities to perform a given task, has been shown to be positively related to learning and motivation across domains [6], academic achievement [7], and likelihood of undertaking challenging tasks [8]. Although self-efficacy has been studied in a variety of organizational and educational contexts, studies involving pre-service teachers have generally referred to self-efficacy for teaching rather than science. For example, Morrell and Carroll [9] used the STEBI-B [10] to investigate pre-service teachers' self-efficacy for teaching science. They found that although methods courses can improve teaching self-efficacy, content courses are often ineffective, except perhaps for those students with very low self-efficacy. In our own preliminary studies, we found that PAT led to positive gains in both physics self-efficacy and physics teaching self-efficacy [11].

In this study, we were interested in how pre-service teachers develop their self-efficacy for performing physics tasks and understanding physics concepts. These beliefs are distinct from teachers' beliefs in their ability to *teach* physics, which was not assessed here. While the former deals with perceptions of one's abilities to engage in specific scientific endeavors, the latter involves additional complications such as one's self-perceived abilities to convey that information to students.

Bandura hypothesized that self-efficacy forms through the interpretation of information from four primary sources: one's own mastery experience, performances of vicarious models, evaluative feedback, and the interpretations of one's physiological and affective state while engaging in a task [5]. However, the literature does not identify what particular features of courses contribute to students' self-efficacy, specifically within science content courses for preservice teachers.

As part of a larger study exploring changes in pre-service teachers' physics self-efficacy, we investigated the following research question for this paper: What features of PAT do pre-service teachers find most influential on their self-efficacy for doing and understanding science? In this context, being able to do and understand science means being able to perform particular science-related tasks that were identified as important within PAT, such as drawing the path of the sun through the sky on a given day or predicting the location of an image formed by a mirror.

PHYSICS AND ASTRONOMY FOR TEACHERS

PAT is an active-learning class that meets for five and a half hours each week. In the classroom, students engage in guided-inquiry activities such as building electric circuits, classifying materials based on magnetic properties, and observing light projected through a small hole onto a screen. These activities are typically done in groups of four, although students are responsible for individual homework assignments, quizzes, and exams. Each section has between 34 and 40 students with one lead instructor and a Teaching Assistant (TA). Instructors rarely lecture; instead, the instructor and TA lead “checks” with individual groups, asking about their investigations and helping the students summarize and reflect upon what they have done. Sometimes an instructor leads a review or class discussion.

All students enrolled in the course are elementary, middle school, or special education majors. Approximately ninety percent are female, and most are enrolled in their third or fourth year at the University.

This study involved students from five sections, taught by three male instructors (A, B, and C) over three semesters. Instructors A and C based their in-class activities on *Physics by Inquiry* [3]; instructor B used activities developed from the University of Kentucky’s Online Physics for Teachers course [12], which is used for in-service teachers. Only instructor C used an online course management system and had his students post to online blogs. His students also completed group projects in place of one exam. Despite these differences, day-to-day mechanics of the classes were similar, and each section covered roughly the same content. All student responses were combined for analysis.

METHODS

A total of 118 students self-selected to participate in this study (see Table 1). Students were asked to rate the degree to which they felt capable of understanding physics concepts and performing related physics activities (e.g., to light a light bulb given a battery and wire). Students were then asked to rate the extent to which class components (e.g., keeping a science notebook) contributed to their self-efficacy and to provide additional comments on these ratings. Specifically, students were asked if there were other events or activities not listed that affected their self-perceptions during the semester (Q1) and, more generally, what ways the course affected their self-perceptions (Q2). A final question (Q3) asked for suggestions of what else could have been done to improve their self-efficacy. Our focus in this paper is on using these open-ended questions to understand the teaching practices that most influence students’ efficacy beliefs in science.

TABLE 1. Participation in study by section

Code	Semester	Instructor	# Participating
S11A	Spring 2011	A	17
S11C	Spring 2011	C	19
F11B	Fall 2011	B	14
F11C	Fall 2011	C	34
S12C	Spring 2012	C	34

Responses to the open-ended questions were tagged by section, segmented when necessary, and coded according to an inductive analysis [13] along two emergent dimensions: valence and contributor (see below). There were 210 responses in all.

Inter-rater reliability was established along each dimension with two coders. Along the valence dimension, we had perfect agreement; along the contributor dimension, we obtained a Cohen’s Kappa of 0.816. Disagreements were resolved through discussion. Open-ended interviews with students from multiple sections supported the results presented here; however, in-depth analysis of the interviews is beyond the scope of this paper.

RESULTS

Themes emerged along two different dimensions. The first dimension, valence, refers to whether comments indicated an increase or a decrease in the participant’s self-efficacy (positive or negative). The second dimension, contributor, refers to the particular aspect of the course the comment referenced. Below, those two dimensions are explored in more detail. It is important to note that some responses – those from the last question about what else could have helped – were not coded for valence as the prompt requested inherently negative responses such as, “I think a book would have helped me [Q3, F11B].”

The number of responses to each of the questions are sorted by both contributor and valence in Table 2.

Valence

Responses that indicated a positive effect upon self-efficacy were coded as being **positive**. Positive items

TABLE 2. Responses coded by valence and contributor

	Q1 (+)	Q1 (-)	Q2 (+)	Q2 (-)	Q3
Instructor	7	7	5	7	33
Group	15	1	11	2	9
Activity	14	3	23	2	10
Repertoire	5	6	27	6	13
Unclear	1	1	2	1	0
Total	42	18	68	18	65

describe how a student's self-efficacy improved, such as, "This course taught me I was capable of teaching myself [Q2, F11C]."

Items that either indicated that the participant's self-efficacy did not increase, or that something lacking from the course could have been added to enhance self-efficacy, were coded as **negative**. Negative items describe either how the student's self-perceptions diminished or how the course missed opportunities for positive impact. In either case, negative items indicated how students' resulting self-efficacy was lower than it could have otherwise been. For example, "I'm less confident, the concepts confused me [Q2, S12C]," and "I also don't feel like I had a good knowledge base for the labs and presentations, [so] lectures before would have been helpful [Q1, S12C]," were coded as negative valence.

Contributor

Respondents cited specific aspects of the course that affected their self-efficacy. Four major themes emerged: the instructors' actions (including those of the TAs), the students' participation in groups, the discrete activities engaged within the classroom (such as hands-on exploration), and the students' construction of their own repertoire of scientific knowledge, processes, and activities.

A small number of responses, such as "I loved the class structure [Q1, F11C]," were unclassifiable, and these were placed into the **unclear** category.

Responses coded as **instructor** describe a direct, explicit influence by the instructor's activities and interactions with the students. These could refer to validation and support of students' efforts or instruction through lecture or "checks." For example, the following statements were coded as instructor: "Our teachers were great. They know how to teach and make you remember. When the exams come around I feel like I know the material well. I felt smarter after each lesson [Q1, S12C]"; "When instructors would come around to our group and ask us questions about our observations, I felt belittled because they asked these assessment questions in a way in which I felt dumb and less confident to answer [Q1, S12C]." Note that in the former comment, the implication was that the teachers' ability to prepare the student led to an improvement in her self-confidence.

Responses coded as **group** describe the influence from interactions with peers. Such comments could range from discussions with individual peers to class-level interactions. For example, one student noted,"I really liked working in groups. The students in my group really helped understand the material compared to if I were trying to work these experiments out on my own [Q1, S11A]."

Responses coded as **activity** describe the impact of the various activities (except for exams) done as a part of the class. These activities could include guided inquiry activities, homework, online blogs, etc.; for example, "Doing a lot of activities with our groups helped my confidence level because usually science is easier to understand when you can see it happen [Q2, S12C]." Note that this was not coded as "group" because the emphasis was on the activities, not on the ancillary fact that they were conducted in groups.

Responses coded as **repertoire** describe the impact of the student owning a repertoire of science knowledge, processes, and reasoning ability, together with activities that she could use with future students. Comments referring to the pacing of the class implicitly refer to whether one has sufficient time to build a repertoire and are coded here. Similarly, student's grades on exams are taken to imply the effect on one's confidence in terms of the validation of one's constructed repertoire. This comment was coded as repertoire: "This class has really influenced my confidence in understanding science. I think it was effective in challenging me to think outside of the box as well as hearing viewpoints [different] from my own and connecting ideas together [Q1, S12C]."

The total number of positive-valence responses to the first two prompts was approximately triple the total number of negative-valence responses. However, the breakdown by contributor shows that most of the negative-valence comments are accounted for in the "instructor" and "repertoire" categories (see Table 2).

DISCUSSION

Although Q1 and Q2 were similar prompts, they seemed to elicit different responses, most notably with respect to the repertoire code. Responses to the latter prompt tended to emphasize that having learned physics content improved students' self-efficacy (e.g., "It has made me more confident because it has given me more experience and knowledge about physics [Q2, S12C]."). Responses to Q1 were not so positive. Only a few referred to how the class helped the students master the physics content; indeed, there was no clear theme in repertoire responses to Q1 other than noting the difficulty of the concepts in PAT.

The balance of negative- and positive-valence comments due to the contribution of the instructor's activities is very interesting, at least in terms of its implications. Although some students seemed pleased by the instructors' efforts (e.g., "...The checks given to us by the professor and TA periodically through each unit were also very helpful... [Q1, S11A]"), others indicated that the instructors had a condescending attitude, which frustrated them (e.g., "I feel less confident because our TA laughs/smirks [Q1, S12C]"). A recurring theme, especially when taken together with the numerous responses to the final question, was a perception that instructors did not provide sufficient guidance or directions for the classroom activities (e.g., "[It would have helped] if we had more guided instruction [Q3, S11C]") or background in the form of lectures (e.g., "I wish there was more lecture. I had to learn all the concepts by myself [Q3, F11B]"). Students also indicated that positive reinforcement bolstered their self-efficacy (e.g., "Receiving gold stars for expert knowledge made me feel good [Q2, F11C]"), whereas negative reinforcement diminished self-efficacy (e.g., "Discouraging comments on the homework [Q2, S12C]"). Overall, the implication was that instructors' actions and behavior had a substantial effect – in both positive and negative ways – on their students' self-efficacy.

A remarkable finding from this study is the contrast between two types of statements about the instructor's role. Some students implied that instructors were being ineffective by not lecturing (e.g., "...I really do not believe in this method of learning because how can a student learn something that they do not know by teaching themselves? Isn't that what the professor is there for, to teach the students [Q1, S11A]?"). On the other hand, some students gained self-efficacy from struggling and figuring out physical concepts on their own (e.g., "Being forced to figure things out kind of on our own helped my confidence in understanding science more than if the teachers had just told us what to do [Q2, S12C]"). This contrast, further emphasized by the volume of positive-valence comments about activities, raises further questions. For example, if performing classroom activities is akin to Bandura's "mastery experience" [5], then to what does lecture correspond? Perhaps students felt uncomfortable about the alternative role of the instructor or perhaps the instruction was too unstructured for them to feel successful. In any case, a deeper investigation into this phenomenon is warranted.

This study included data from five semesters with three instructors at the same university, with a population entirely consisting of education majors. Therefore, one should be cautious about generalizing these findings to other courses or similar courses at other universities or with other populations.

CONCLUSIONS

Multiple aspects of PAT emerged as contributing to students' self-efficacy in PAT, which reflects the complexity of self-efficacy development as noted by Bandura. Working in groups, doing class-related (mainly guided-inquiry) activities, and building a repertoire of physics content and experiences were all seen to be positive influences on students' self-efficacy, whereas the instructor's activities and behaviors, including social persuasions, seem to influence self-efficacy in both positive and negative ways. The tension between the value students placed on both struggling to figure out a problem on their own and wanting lecture presents a curious dichotomy that is worth further study.

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