Reformed Physics Instruction Through The Eyes Of Students

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Abstract. This paper reports on a qualitative study of students' responses towards innovations in an introductory physics course: their attitudes toward the change; their perceptions of the learning methods and the subject; and the relationships among these variables. We found that students' ideas about learning affected their reposes to the reforms.

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INTRODUCTION

For the past five years the Rutgers PAER group has been modifying "Physics for the Sciences" - an algebra-based course for science majors at Rutgers University. Presently the course follows the *Investigative Science Learning Environment* [*ISLE,* 1] that facilitates authentic science learning.

Sadly, anecdotal student reactions indicated that the transition from traditional courses to this innovative learning environment was difficult. We decided to conduct a study to answer the following questions: How do students respond to new teaching methods? Do they perceive differences between "traditional" science classes and constructivist approaches? If they see the differences, do they appreciate the changes? What factors affect their responses to new teaching?

Answers to these questions will help facilitate the adoption of new teaching and learning practices.

PHYSICS FOR THE SCIENCES

"Physics for the Sciences" (193/194) follows the *ISLE* system where students construct their own knowledge and acquire scientific abilities by emulating the research practices of physicists. They start every conceptual unit by observing physical phenomena; collecting data, analyzing them and inventing multiple explanations. Then, using hypothetico-deductive reasoning, students test the explanations, revise them and apply the new knowledge to solve problems. They work in groups and are active learners. Instructors do not provide students with physical concepts or laws but create the conditions and support for learners to construct physics knowledge. A crucial resource for students is the Active Learning Guide [2]. It consists of sequences of activities that facilitate the construction of physics concepts and scientific abilities. During 2005-2006 students did not have to purchase a textbook but acquired the ALG and worked tasks in it. In the lab students designed their own experiments supported by lab write-ups and scientific abilities rubrics [3]. The former did not have detailed directions on how to conduct an experimental procedure, but had guiding questions and prompts.

During the academic year when the study was conducted the instructor in charge was enthusiastic but lacked experience. The majority of the lab and recitation TAs had never taught.

PREVIOUS WORK

Although extensive literature explores the effects of teacher attitudes on the success of reforms, students' opinions are much less investigated. Fawcett [4] suggested that students go through three different stages: comfortable dependence, anxiety and comfortable independence. He found that the change takes time and creates concern and fear in students.

Hammer found that students' expectations and attitudes help explain learners' performance in introductory physics courses [5]. UMPERG created the MPEX survey [6] to probe students' thinking about physics and learning. They found that there is a large difference between novice and expert attitudes and discovered that student expectations tend to deteriorate with instruction. Similar results were found by the

CP883, *2006 Physics Education Research Conference*, edited by L. McCullough, L. Hsu, and P. Heron

Colorado PER Group using the CLASS instrument [7].

METHOD

Rationale: Due to the nature of the posed questions, we believe that the most appropriate approach is an exploratory qualitative study. We have to identify the relevant variables triggering students' responses and study the interactions among students' perceived expectations, abilities and beliefs about physics knowledge. We need to: identify the different ways in which students' may respond to change; describe the context and conditions that may prompt various kinds of students' reactions to innovations; and point to the possible causes. This approach is called a grounded theory [8] which explains a set of observations makes predictions within certain boundaries.

In a grounded theory a theoretical model is generated through the collection and analysis of the data [8]. It is crucial to try to not anticipate possible outcomes during each phase of the study, in order to not impede the emergence of the actual model. There are three steps in the data analysis in the grounded theory: open coding, axial coding and selective coding.

Population and data collection: There were 170 students in "Physics for the Sciences" 193/194 during the academic year of 2005/2006. The population was quite heterogeneous. Some students were interested in environmental, exercise sciences, pharmacy, chemistry or medicine. Many wanted to maintain a high GPA and this contributed to their high stress level.

We used the data from interviews with nine students. We collected data during the last weeks of a two-semester course. In April/May 2006, the instructor in charge asked for volunteers. As we were especially interested in investigating the circumstances and ideas of students opposed to the reformed course, we invited two students who had previously expressed strong opinions against the course teaching and learning methods. Due to the small sample we cannot claim that the participants represent the whole class.

We conducted nine 45-minutes individual interviews. Students' responses were audio-taped and transcribed. Researchers were not instructors in the course and we conducted interviews in neutral, non-threatening spaces such as student centers and university gardens. The interviews were semi-structured, with the general aim of getting the students to talk about their experiences in the course. The researchers used the predetermined sequence of questions but tried to keep the questioning conversational. Some of the questions are listed below.

a) What do you think about physics in general?
b) How is Physics 193/194 similar to or different from other science classes that you had or you are taking?
c) What do you like the most and the least in 193/194?
d) Tell me about your experience in taking 193/194.
e) What do you think about 193/194 teaching methods?
f) Have your ideas about physics changed somehow?
g) How would you describe your performance in Physics 193/194?

The goal of open-ended questions was to access the students' perspective and to learn about students' understanding and judgments in their own terms.

Data analysis: During the open coding phase, we examined the data by breaking them into small portions and trying to identify different categories. We were guided, in part, by the language of the students describing their experiences. The categories for the textual words of the subjects are called "in vivo" codes. However we were cautious because different people may use the same worlds differently therefore it is important to capture the meaning. For example, consider the meaning of the word "learning" when used by one of the students in the interview: "I'm learning more in chemistry, but how much am I going to remember in chemistry? I would not be confident with my ability to do a chemistry problem. But I might be more confident in my way to solve a physics problem. I mean I can spit out a physics formula for you and understand what they mean, but chemistry I couldn't."

The appearing codes were compared and contrasted with one another to reduce the amount and to obtain a small number of refined categories that constituted the most important ideas of the study. The procedure continued until the categories were saturated - the analysis of the texts did not produce any more codes and many events in each category supported the codes. Axial coding followed the open coding. There, the open codes were reduced to several categories and the data in each of category were judged against that category's properties. We used a theory-generation software package named Atlas.ti [9], developed for such studies. In the final phase, selective coding, we related the core category to the other categories by creating a visual representation of the interrelationship among them (Fig.1).

FINDINGS

Our analysis yielded the following categories:

(1) *Attitude:* Positive or negative students' disposition toward the course.

(2) *Perceptions:* Students' awareness and interpretation of several relevant aspects of the course. Students' perceptions affected their attitudes.

(2a) *Course Purposes:* Students' understanding the goals of the course and the purposes of learning tasks.

(2b) *Learning:* Students' thinking of how they learn.
(2c) *Difficulty:* Students' perception of the affordability of the course goals and effort required.
(3) *Variableness*: Changes in students' perceptions and views of physics and the course.

Attitude Overall, most of the students expressed positive feelings about the course. However, we saw a wide range of responses. Some really enjoyed the course: "for a science class I feel that this is one of the better ones". Some could barely tolerate it: "I just think [the class] it's stupid". Others were content but not passionate: "this is not a bad class to be required to take". The majority appreciated some aspects and decried others or fluctuated in their support for the format and methods: "We needed to figure it out which was good and bad I mean it was frustrating but it made us really think and figure it out on our own."

Course Purposes Many students understood some of the different goals for the course: for example, the development of understanding and to a lesser degree the acquisition of scientific abilities. "I feel like I understand much more of the aspects in terms. I have trouble accepting things and I have to accept things in physics, but in this course I have to accept less of them and understand more of them". Another student said "I know like the course wants to teach us how to approach a topic scientifically like with hypothesis, prediction and everything."

However a disturbing fact was that most of the students at one or another instance mistook or ignored the objectives and had difficulty understanding the purpose of many of the tasks that they were asked to complete. For example, some of the students complained that labs and large room meetings were not always synchronized because a lab activity occasionally preceded a corresponding large room meeting about that same topic. On the contrary, labs and lectures were carefully matched, and in some cases the lab activities served as preparation for the whole class discussion. This fact was problematic for some students. Similarly most of the interviewed students complained about having to calculate the uncertainty for every quantitative result in lab: "We understood after the first lab that the uncertainties are important but we didn't need to be pounded into our heads for the next ten labs in 193 and then the entire eleven labs in 194, calculating them every single time for every single instrument." One student protested to using multiple representations "different ways of representing motion… I'm never going to use that… and I don't remember... they're like convention." These misunderstandings might have triggered negative reactions to the innovations.

Learning We found that some students believed that they learned by reading or listening to information: "I read the book and then I do practice problems". Others argued that listening to instructors or consulting a textbook was not enough; that they needed to engage in other activities to learn: "Lecture is interesting and can be fun but you are just sitting there and you're having one person tell you what you need to know and you are not grasping the concepts." Those, who thought that they needed "to figure out things on their own", were much more inclined toward the course.

Difficulties Those students who found the subject or the assignments difficult tended to reject the innovative course. Most of the students reported arriving on the first day of class thinking that physics was a very difficult subject. When they faced goals, tasks or epistemologies that were in dissonance with those in their prior science classes, their perceived difficulty of the course increased. "I came in with the mentality that physics is the devil", or "I wasn't looking forward to physics actually back in September cause thinking back to high school I just remember being very confused and like frustrated." Several felt that they lacked the aptitudes needed for physics: "some things in physics don't click with me", "physics is important, it's just not for me". In this state of mind encountering unfamiliar goals or tasks increases the level of students stress: "I was pretty surprised, I was like this isn't physics class cause normally when you first in general physics you go to lecture and you get Newton's Law right, but then here it's like today it's like observation, experiment, and everyone was like huh? It feels like this kind of too broad, I'm confused, and in the beginning I feel like oh I'm not really learning anything." Students did not expect new goals and tasks. They also found the idea about the nature of science embedded in the course was different from their previous notions. Students experienced this as an unsetting feature that attributed to physics and not to other sciences: "Biology for me is a hardcore factual thing subject, that can be understood by facts... but physics on the other hand is really like a guess and check type science. I like something with a solid answer", "I find that like biology or chemistry is more factual by the book type thing where physics can be… it changes according to the circumstances you are looking at" and "maybe physics in general isn't as straight forward as other sciences."

Variableness There was a clear trend in students' opinions. Students recalled that became significantly more positive about through the academic year: "I think it's an overall better feeling, for whatever reason it took a while to understand the goal". This transition is best represented by a student who said that if given the choice, "I'd probably pick calc based physics in this format because there are aspects of 193:194 (*number to designate the course)* that are very good and the recitations are awesome ... I would take calc

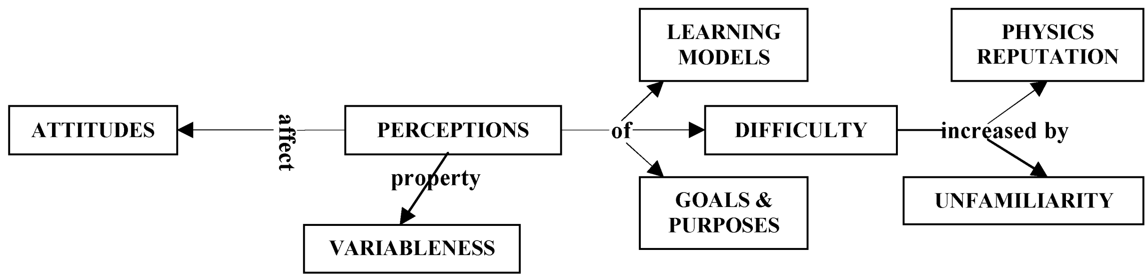

FIGURE 1. Model for students' response to the innovative physics course

based in this format because of the demonstrations and cause I think things have taken pretty good detail without the calc. With the calc, I think it would just explain stuff perfectly." She added: "I actually learned a lot in lab this semester." However, "I hated this class when it first started. I hated going to lecture, I hated going to lab." Therefore students' perceptions can change modifying their attitudes.

The findings are represented in Figure 1.

DISCUSION AND IMPLICATIONS

Our overall impression of the results of this study was quite positive. Students focused their narratives mainly on issues of learning and not on grades. Most of them expressed positive judgments about the course and its learning methods. More importantly they enjoyed the course for the reasons that education researchers had in mind when they developed the philosophy, the goals, structure and tasks in the course supporting students actively constructing meaningful knowledge. As students said: "it helps you figure it out, and that's, you know, you have your notes from lecture that you can refer to, but it's really you trying to bring it all together". Other facets of the course that students appreciated were their collaborative work and the demonstrations during large room meetings. By contrast, the majority of the interviewed students complained about aspects that were not essential to the reform. In fact major sources of dissatisfaction were the rush during the last minutes when the instructor tried to finish his lesson plan and the large amount of writing required for lab reports. Students' most frequent complaint was that no textbook was assigned. It created a feeling of uneasiness and insecurity among them. They missed something "solid" that would have supported their developing concepts.

The ideas that the individual student held about learning were an important factor affecting the easiness of how she or he embraced the reforms. Those students who believed in a transmission paradigm of knowledge were more likely to reject the *ISLE* course. They thought that they did not need all the hassle, extra effort and increase of time because they learned by listening to the lecturer and reading the book. During interviews we observed many students in mixed epistemological states, appreciating their active engagement and learning responsibility only at times or for certain aspects of the process.

Students' lack of knowledge about learning led to misunderstanding of course and assignments goals. This is particularly disturbing because the instructors made a special effort to communicate those objectives to the students in documents included in the course package. Student learning development must be an essential outcome of any course. We need to communicate this objective explicitly and implicitly, in the design of assignment and assessment. It might be helpful to students to take course on epistemology.

Many students mistrusted innovations because of malfunctions due the inexperience of the instructors or to the novelty of the approach. Therefore when implementing innovations, a special effort must be made to train TA's and support instructors in their process of adjusting to new formats.

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