Choosing to Major in Physics, or Not: Factors Affecting Undergraduate Decision Making

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Abstract
For the past 40 years, there has been apprehension in North American society, and particularly in the scientific community, concerning the decline of interest and enrollment in science degree programs at the post-secondary level. This trend has proven very difficult to reverse. The purpose of this study was to explore why students at an Atlantic Canadian university pursue a major in physics, and why other eligible students make different choices. Both the students themselves and their physics professors were consulted in the course of this investigation. With a post structural, constructivist theoretical framework, an instrumental case study of this university is presented using a qualitative online survey for students and semi-structured interviews with their professors. Data from this study supports the theory of physics identity proposed by Hazari et al. (2010). The themes reflected the four dimensions of physics identity, namely, interest, recognition, performance, and competence, with interest appearing as the most important of the four. One additional dimension, the *career prospects problem*, was reflected within the themes of this study. This research begins to address the concern of low enrollments by examining the decision-making process of first-year physics students to stay-the-course or to pursue other options with a clear indication that as physics educationalists, we need to clearly articulate viable career options available to those who hold an undergraduate physics degree. Else, students will choose degrees whose career paths have been clearly labeled by society.
Keywords: Undergraduate physics; Enrolment; Physics identity; Case Study.

INTRODUCTION

The field of Physics Education Research (PER) is, in part, concerned with keeping students enrolled in physics courses long enough to fill society's need for scientifically literate citizens (Tobias, 1990; van Aalst, 2000; Wieman and Perkins, 2005). With that in mind, this article focuses on the choice that first-year undergraduate students in introductory physics classes make about whether to continue on to major in physics or not. The vast majority of these students decline to pursue a major in physics (Mulvey and Nicholson, 2011; Nicholson and Mulvey, 2013). McDermott (1990) noted that "physics majors are typically about 1 out of every 30 students in the [introductory] class," (p. 302) a statistic that has not substantially changed in the past twenty or more years. There may be many reasons why eligible students choose not to major in physics, including lack of interest (Perkins and Gratny, 2010), a perception that physics is difficult (Angell et al., 2004), gender-based issues (Gonsalves, 2012; Hazari, Tai, and Sadler, 2007), and lack of encouragement from role models (Hazari et al., 2010). This study aims to determine the reasons for students' choices to remain in the field of physics or why they choose a different path at a university in Atlantic Canada. Results from this study have transferability to other physics departments and allude to best practices which departments may want to consider as a means to maintain or increase enrollment.

CONTEXT OF THE STUDY

This research was conducted in a physics department in Atlantic Canada. Two first year physics courses were included in the study. Physics 1A and Physics 1B are pseudonyms for the two halves of the calculus-based introductory physics course for students interested in pursuing degrees in physics, chemistry, engineering, or pre-medical studies. This class, Physics 1A/B, of approximately 150 students met in a large lecture theater for 3 hours of lecture per week, and in separate sections of 30-50 students each in a laboratory session for 3 hours per week. Physics 2 is the pseudonym for a one-semester, first-year course in modern physics that is required for those majoring in physics. This class of 23 students met in a smaller classroom for three hours of lecture per week during the winter semester. The professors for both these courses, Physics 1A/B and Physics 2, used research-based strategies in these courses, such as conceptual questions, peer discussion, and interactive lecture demonstrations, with the goal of improving student learning.

All students in Physics 1B and Physics 2 were invited to participate in the study, along with the course professors. The total number of students who were invited was 135 as some students were enrolled in both Physics 1B and Physics 2. The number of participants was very low, N = 14, and the possible reasons for this low return rate are discussed in the results. However, from the data set, the majority of student participants self-identified as people between the ages of 17 and 20, who enjoyed physics, had a high or very high-interest level in physics and had achieved grades of A of higher in Physics 1A. Identified gender of the group was split; 64% of the student participants identified as male and 36% as female. The professor who taught Physics 1A/B and the professor who taught Physics 2 both participated; they have doctoral degrees in physics, and both were tenured with at least ten years' teaching experience. The Physics 1A/B professor was male, and the Physics 2 professor was female; both have an interest in physics education research.

LITERATURE REVIEW

There has been much interest within physics departments and the physics education research community in understanding what draws and influences students' decisions in pursuing physics and physics degrees. There is agreement in the physics community that more graduates from physics programs and greater diversity among these graduates are both needed and required in order to improve science itself (Aguilar, Walton, and Wieman, 2014; Dean, 2007; Hazari et al., 2010; Malcom, 1990; Tobias, 1990), and society as a whole. Studying why students choose to major in physics, or not, during and after the introductory physics course, could partly answer the call of Tobias:

> *Introductory science [is] where the first painful shakeout is expected to occur. …We need to enlarge what has hitherto been considered the natural pool of recruits to science and be willing to offer new kinds of students a welcome and a chance for success. … We are obliged to think and think hard not just about who does science and why, but who doesn't do science, and why not. (1990, p. 10-12).*

Students come to university with a wealth of background experiences relating to physics and science, as shown in Figure 1. They have experiences in their families (Hazari et al., 2010; Woolnough, 1994) and at school (Harlow, Harrison, and Meyertholen, 2014; Hazari et al., 2010; Woolnough, 1994), which are interpreted and influence that they are as individuals. They have experiences that are differentiated based on their gender (Hazari, Tai, and Sadler, 2007; Hazari et al., 2010). They may or may not have had extra curricular experiences in physics-related areas (Hazari et al., 2010; Woolnough, 1994). It is the combination of these individual impacts on a student that builds her/his *physics identity*, defined by Hazari et al. (2010) as the degree to which a person sees her/himself as a "physics person". The physics identity has four dimensions: interest in physics concepts, past performance in physics-related courses and activities, competence to solve physics-related problems, and recognition as a 'physics person' by others such as parents, teachers, and peers. Having a strong physics identity, according to Hazari et al., predicts persistence in physics.

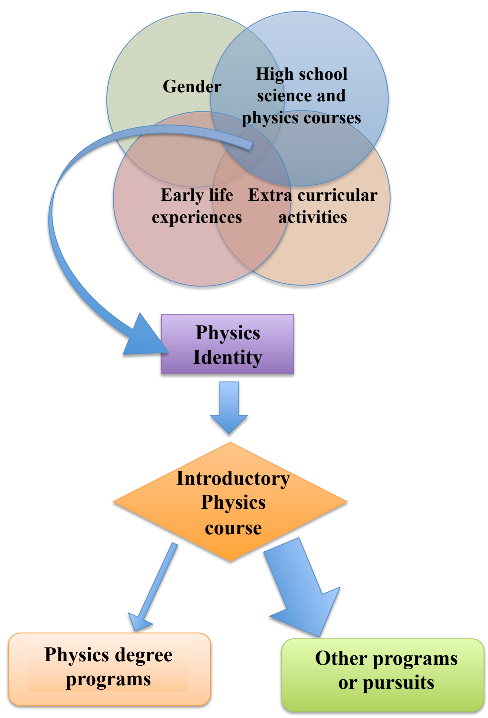

Figure 1. *Influences on Students Before and During Their Choice of Major*

Moving forward with this definition, a student's physics identity is, then, an influence on the student before and during his or her introductory physics course. At this point, students make a decision about whether to major in physics or not. Most choose not to continue in physics, but a few do persist. The question that needs to be answered is why?

Because it is the "last stop" before most students leave physics, the introductory university physics course is an appropriate venue in which to study the reasons people leave physics or persist. As physics educators, we need to pay strict attention to this course, both its contents and its delivery, because student success here is critical to them (a) continuing in physical science fields and (b) considering whether to stay within the area of physics. Poor introductory physics courses steer students away from these fields and lead, at the surface, to decreased enrollments. Perhaps even more importantly, providing the first year students with less than our best can create a questionable understanding of scientific literacy and the connections between science, today's society, our environment and how technology is influencing our world.

Generally, the introductory physics course involves a large lecture hall experience with a passive learning environment, plus a "cookbook-type", time-pressured, laboratory experience which may or may not be connected to the lecture experience. Students are expected to complete large volumes of work each week, which encourages rote learning rather than critical thinking, analysis, and evaluative opportunities (Aikenhead, 2006; Harrison, 2014; Wieman and Perkins, 2005). Redish and Hammer (2009) wrote: "The idea that one has to cover a particular set of material, whether or not the students understand it, seems peculiar, but it is widespread" (p. 16). Many professors would say that they expect their students to think deeply and critically about the course material, and yet maintain the unreasonable work volumes. These teaching methods work for the small minority of students who would have pursued physics anyway, but do nothing to encourage other students (Tobias, 1990). In fact, traditional introductory physics courses have been shown to decrease student interest and degrade their expert-like beliefs in physics (Perkins et al., 2006).

PER has shown that curricula with interactive engagement (IE) strategies make it easier for students to incorporate new concepts into their existing self-identities, rather than suspend or change deeply held beliefs about the world (Aikenhead, 2006; van Aalst, 2000). Using a conceptual, rather than a mathematical focus in a course can also have significant benefits (Hazari et al., 2010; Saul, 1998; van Aalst, 2000; Wieman and Perkins, 2005). PER-based curricula have been shown to increase the number of students who continue on in physics programs (Adams et al., 2006; van Aalst, 2000).

It is also important for students to enjoy their physics course, or they will likely not continue. Tobias (1990) squarely blamed the introductory physics course for the decreased interest and enrollment that had been observed at that time. She found that students in her study either did not like or in some cases, hated their introductory physics course. Woolnough (1994) agreed:

> *It is no use teaching physics so that students know a lot or can do a lot if they do not enjoy and want to do it…. Perhaps the strongest message that comes through these researches [sic] is the need to concentrate on the ways to develop the students' affective response, so that they find personal satisfaction in doing science and thus want to continue with it (p. 370).*

THEORETICAL FRAMEWORK

This research uses an instrumental case study methodology (Stake, 2005) and holds its theoretical framework in a post structural, constructivist paradigm. Poststructuralist belief systems acknowledge that although all human values and thoughts are based on oppositional ideas of race, gender, culture, and class, these categories do not define us, and language cannot adequately reflect all the influences on a person's thoughts and decisions (Kvale, 1992). Human experiences are usually complex and nuanced, making them impossible to describe or understand fully, especially within the confines of our languages. This research and the process of choosing a degree program involve many such experiences and thus are suited to a post structural perspective.

In the constructivist paradigm, all knowledge is relative and transactional: nothing can ever be fully known except by the specific knower and in the specific circumstances where it was first experienced (Guba and Lincoln, 2005). Knowledge of the human race is constructed piece by piece, by collective consensus around what experiences are and what meaning they have. Knowledge of the specific can only be generalized tentatively and by collaborative consultation with multiple stakeholders, by weaving together what we can describe of our collected experiences. Guba and Lincoln wrote that "there is no single 'truth' – … all truths are but partial truths" (2005, p. 212), and this applies to the decision of whether to major in physics because each individual bases this decision on his or her own interpretations of his or her past and current experiences in physics and on others' reactions to the sharing of these experiences.

This study employed a qualitative case study methodology. In this case, the phenomenon of interest is students' decision making around the selection of a degree program, which is a highly individual, contextual choice made using information gathered both consciously and unconsciously over many years. This information, the interpretations of it, and its effects may be known only to the students making the decisions, and in some cases may even be unknown or unacknowledged even to themselves. Therefore, soliciting this information was best done using a qualitative methodology.

Within this framework, asking the students what they thought about the decision-making process, and listening to their interpretations of their own experiences, was an appropriate study design. In addition, the introductory physics instructors were interviewed about these courses (Physics 1B and Physics 2), in order to develop a broader sense of this group of students and how it compared to previous years. The intent of the study was to provide some insight for future classes, and/or classes at different universities, based on the experiences and the decision-making process of the individual students of this particular class. Once ethical approval was obtained, invitations and data collection began.

Students completing Physics 1B and/or Physics 2 were invited to complete an online, voluntary, anonymous survey about their experiences in physics in general, this particular physics course, and how they chose their major. The introductory physics professors were interviewed to gain insight from their perspectives about students' choice of major. Documents such as university websites and professors' course outlines were consulted to provide in-depth background information about the physics department and the requirements of students within the courses and the degree programs. Qualitative responses from the student data set as well as the professor data set were analyzed for common themes and categories. These methods of data collection and analysis, when used together, formed an in-depth picture of the first year students' decision-making process about physics.

RESULTS

This study collected data from 14 of 135 eligible students, and two of two eligible professors. The organization of the themes that arose during the data analysis can be seen in Figure 2. The four dimensions, namely, interest, competence, recognition and performance, are based on the work of Hazari et al. (2010). The figure shows that both the students and the professors voiced many of the themes already found within the literature. Interestingly, one theme that emerged which was not discussed in the original definition of physics identity (Hazari et al., 2010): the *career prospects problem*, which is discussed later in this section.

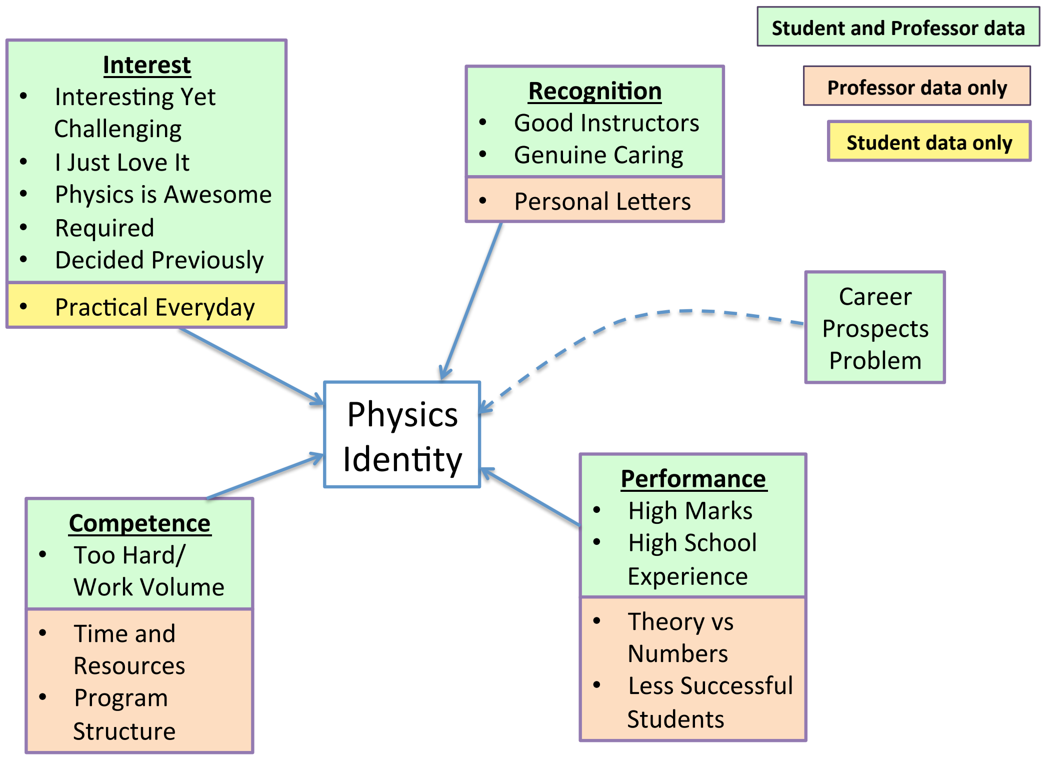

Figure 2. *Themes arising from The Qualitative Analysis, and How They Seemed To Be Interrelated. The Four Dimensions of Interest, Recognition, Competence and Performance Are Part of The Definition of Physics Identity.*

Student Perspectives

The student data in this study supported the theory of physics identity (Hazari et al., 2010), in that their stated influences could be classified into the dimensions of interest, recognition, competence and performance. The most important of these four dimensions was interest, with students commenting extensively about their interest level in physics and their profound love of the subject. The student participants used the phrases *I just love it* and *physics is awesome* to describe this strong emotional connection. Students also discussed how they liked the fact that physics was interesting in a *practical everyday* sense, which was not mentioned by the professors. The most popular comment from students was that they found physics interesting, yet challenging, and the next most popular comment was that they had decided previously, that is, before coming to university, what their major would be, both for students intending to major in physics, and for those planning to take another route. Many students also declared that they were taking Physics 1B or Physics 2 because it was required for their desired degree program.

Recognition by role models as a "physics person" also influenced students to decide to major in physics. Student participants praised this university's first-year physics instructors effusively, and several also mentioned influential high school physics teachers. Every student in this study (100%) made a statement about the excellence of their university physics instructors, even those who did not like physics and/or were not interested in continuing in the field.

Students' past performance in physics was a factor in the decision about whether to major in physics or not, although not simply as a direct relationship between high marks and the strong likelihood of continuing in physics. Most students participating in this study had had positive experiences in high school physics. Students in this study who had earned high marks in past physics courses did sometimes choose to pursue it as a degree program. However, some students with high marks chose to pursue other majors, citing interest in another subject as their deciding factor. In addition, some students with lower marks in physics were considering pursuing physics as a degree despite their lower marks, again with strong interest playing a decisive role. These students cited concerns about their competence in physics as a major factor in their decision-making. Students worried that a physics degree would be too difficult, and the workload too high, for them to succeed.

The *career prospects problem* was another factor in this study, and it does not align well with the four dimensions of physics identity. However, the issue of what to do with a physics degree is discussed elsewhere in the literature (Camporesi, 2001; Oliver, 2010), and it does fit with the general concept of physics identity, in that a person's self-identified connection with the subject would be affected by his or her ability to imagine a clear path through a physics degree towards a physics-related career. The difficulty in being able to clearly articulate the value and versatility of a physics degree is important and is a possible avenue for further investigation.

Professor Perspectives

The professors' input to this study also aligned well with the theory of physics identity discussed by Hazari et al. (2010). The professors' data agreed generally with the student input, but also provided extra information for the dimensions of competence, recognition, and performance. For the purposes of the study, one professor was assigned the pseudonym "Kelly", and the other the pseudonym "Alex".

Kelly cited student interest level as the most important influence on decision-making, with the love of the subject playing a role. Alex referred repeatedly to his efforts to try to keep students interested in the course material, using various strategies. Both professors discussed the other three dimensions in greater detail than the students did, with reference to *theory vs. numbers* and *less successful students* falling under the performance dimension, *personal letters* under recognition, and *time and resources* and *program structure* under competence. In particular, the professors recognized that physics degrees are very difficult, and the expected workload is daunting for students. Generally, the professors accurately reflected the concept of physics identity as discussed by Hazari et al. in their contributions.

Alex discussed the *career prospects problem* extensively, referring to past efforts to mitigate it (Canadian Association of Physicists, 2010; Rigden and American Institute of Physics, 2002) and stories about several former students who had trouble seeing how to apply their physics degrees. The career prospects problem fits with the general concept, but not the four dimensions, of physics identity, as discussed above.

Educational Importance of the Study

Convincing more students to persist in physics would benefit science in particular, and society as a whole, because the specific mentality developed during a physics degree is beneficial to a broad range of industries. However from the results of this study, it is not enough to say this; professors need to show and prove this to students, displaying a clear path to employment identification. In addition, having a wider variety of people contributing to physics will extend the range and applicability of science. As a result of this research, a number of recommendations and possibilities are raised for physics and education faculty to consider.

Students' praise for their instructors in this study was effusive. 100% of student participants commented in some way on their instructors' excellence. The instructors also demonstrated their caring about students and about their courses during their interviews. As the introductory physics course has been shown to be important for both physics and non-physics majors (Hake, 1998; Haussler and Hoffmann, 2002; Hazari et al., 2010; Seymour and Hewitt, 1997), we recommend that all universities give serious consideration to encouraging and supporting good instructors to take on the introductory courses, and put in the necessary work to incorporate PER-based strategies such as using a stronger conceptual focus, employing peer-to-peer learning strategies, and applying physics content to topics of student interest.

The participants in this study indicated that strong feelings about physics (either love or hatred) were important influences on their decisions about whether to major in physics or not. Some said that they had already decided on a major before coming to the university, because of where their interests lay. This finding confirms the need for greater emphasis on development of positive physics identities during the K-12 school years (Cleaves, 2005; Harlow, Harrison, and Meyertholen, 2014; Hazari, Tai, and Sadler, 2007; Hazari et al., 2010; Woolnough, 1994) and the connecting high school teachers and first year physics professors so that the transition is seamless and misunderstandings are reduced.

The student and professor participants in this study agreed with the research literature (Aikenhead, 2006; Harrison, 2014; Perkins et al., 2006; Redish and Hammer, 2009; Wieman and Perkins, 2005) that sometimes, physics is just too hard, either because the concepts are too difficult to grasp, or because the work volume is unreasonably large for the available amount of time. This was a consideration for three of the students in their choice of major and should be investigated further.

Alex stated that there was a suggestion afoot that the program structure be redesigned, such that upper year students had a wider variety of options in their courses. Although quite controversial, this sweeping change could potentially reduce the significance of the career prospects problem, because more specialized upper year courses, such as acoustic physics and medical physics, would provide a view for students to see the inter-disciplinary connections between physics and other disciplines, a point that physicists know and understand but often do not share with students for a variety of reasons.

Limitations

This study was limited by a small sample size, however, it provides a glimpse into the decision-making process that undergraduates go through when deciding whether to major in physics or not. The online and voluntary nature of the study may have created a selection bias: only those who were interested in physics would be interested enough to participate in an online survey. This problem has already been addressed by repeating the study using a paper survey, and the response rate has quadrupled. In the second iteration of the study, the authors hope that with the greater participation rate, a better understanding of the reasons behind the choice not to continue in physics will be possible. In addition, we hope to answer the question, for those who have changed their minds about their major during the course, what was the cause of this change?

An initial read of the new data indicates encouraging possibilities. Firstly, there were a few student participants whose opinion of physics changed during their first year of university. Secondly, the theme of *interest* remained important for a large number of the students in the second cohort of participants. And thirdly, the course instructors were again an important influence on students' decision making. There were also many more comments regarding the Career Prospects Problem in the second group, which may allow a further analysis of this concept.

Although the literature (Hazari, Tai, and Sadler, 2007; Haussler and Hoffmann, 2002; Haussler and Hoffmann, 2000; Stadler, Duit, and Benke, 2000) led us to believe that there would be some gender effects in this study, none were observed. In the second iteration of the project, an initial read of the data shows that roughly 20% of both the male and female participants had decided to major in physics. Some significant gender effects may yet become apparent with further analysis.

CONCLUSIONS AND NEXT STEPS

The data presented by student and professor participants in this study supports the theory of physics identity (Hazari et al., 2010), including the four dimensions of interest, recognition, competence and performance. Interest was the most important factor that influenced student participants' choice of major. Recognition, competence and performance in physics also appeared in this study.

The career prospects problem does not fit directly with the four dimensions of physics identity: interest, performance, competence, and recognition. However, the question of how a physics degree can be applied in careers has been noted elsewhere in the literature (Camporesi, 2001; Oliver, 2010) and should be considered as a factor affecting decisions about whether to major in physics. Determining whether and how the career prospects problem fits with physics identity is a question for future research.

Students in this study with positive physics identities, including a strong interest in the subject coupled with strong past performance, feelings of competence, and/or the experience of having been recognized by a good instructor, chose to major in physics and those with one or more of these factors lacking chose other majors. Based on these results, universities interested in encouraging more students to persist in physics should consider the four dimensions of interest, performance, competence and recognition in order to help build positive physics identities in their students, which we believe will positively affect their chances of continuing in physics.

Encouraging more students to pursue physics degrees is important, because "physics is the liberal arts education for a technological society" (Pimbley, 1997, p. 46). The more technological our society becomes, the more important it is for students to learn the disciplined problem-solving methods of physics. In order to do that, they need to develop positive physics identities, including being interested, falling in love with the subject, and believing that physics is awesome.

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