Educational Technology in Introductory College Physics Teaching and Learning: The Importance of Students' Perception and Performance

Jean Chen, Assistant Director, Office of Institutional Research
University of North Dakota, Grand Forks, ND 58202-7106

Abstract
In this paper the researcher explored how introductory physics student perceptions about learning physics and their perspectives about physics instructors' presentational formats might be developed. Within a constructivist framework, it is of fundamental importance that the educators understand and address student expectations about effective instructional methods and educational technology-integrated curricula in particular. The researcher also investigated the likely impact of student expectations of learning outcomes as part of the implications of improving the approach towards teaching.

Introduction

Physics is a science composed of well-founded expectations of how the natural world should behave, and it uses the tool of mathematics to describe these behaviors (Foster, 2000). Physics learning therefore involves observing phenomena, quantifying the observations, and synthesizing the results into theories (Williams, 1999). The traditional approach to instruction is to teach physics through solving problems. Students of physics are expected to learn both the descriptive or conceptual side of physics and its predictive, problem-solving, and logical reasoning aspects. Because learning logical thinking is difficult, many students try to memorize formulas and recall results from the homework problems at test time. Hammer (1994) reported that many students learn by rote because they have a naive conception of what it means to understand physics. Formulas and equations are important for physics because physical quantities have to be calculated by using them. However, if students cannot understand the physics behind the formulas, they usually will not be able to solve the problem. Elby (1999) focused on another cause of these study habits because many students believed that a deep understanding of physics is not necessary to obtain high grades in physics course.

The American Physical Society (Neushatz & Alpert, 1994) reported that approximately 360,000 students take introductory physics at the college level every year. Saul et al. (2000) indicated that physics educators reported that many students who took introductory physics with traditional lecture and laboratory instruction had the following difficulties: 1) a weak grasp of basic physics concepts, 2) an inability to apply what they know to new situations, 3) a belief that physics is just a collection of equations and procedures, 4) a belief that physics does not have anything to do with their everyday life, and 5) the failure to see physics as a process of trying to make sense out of the physical world.

For physics majors, the basic understanding achieved in introductory physics is the foundation for all subsequent study in physics. Introductory physics is also often a required course for many other academic majors. These students constitute the educated electorate of the future, and their introductory physics may be the only physics courses that they ever take. While success in introductory physics opens the door to opportunities in engineering, medicine, and scientific research for students, failure in these courses closes those career options and presses students toward non-science fields.

Tobias (1990) reported that students who do poorly in the introductory physics courses "are not dumb, they're just different." It is essential for physics instructors to understand what knowledge students bring into the introductory physics classroom and how they respond to instruction (Bao & Redish, 2001). Finding ways to connect students, especially females, has been a focus of physics education research for more than three decades. Numerous programs, innovative strategies, and culturally inclusive curricula have been developed to address the problem. Yet the problem remains. At present, little is known about the relationships between student performance in introductory physics, learning perceptions, and the effectiveness of integrating instruction technology to enhance learning and cognitive processes.

Project Overviews

Most physics instructors want to make the classroom a place where students are encouraged to test ideas, make connections among subjects and content areas, explore problems and issues, work cooperatively, and become lifelong learners. They believe that students must be intellectually engaged and actively involved in their learning, and that traditional instruction is likely failing to provide this engagement. Tremendous efforts have been made by educators to help students learn physics. Peer group and collaborative learning have been introduced into physics classrooms. Collaborative learning promotes communication of ideas and understanding of concepts.

In addition, innovative courses using interactive strategies and educational technology were developed or adapted from existing curricula in an effort to increase student understanding of the concepts. More and more physics instructors use websites as an additional tool to approach their students. Web-based homework problems and tutoring provide additional help to students. Many instructors utilize computer simulations and new ways of presenting end-of-chapter problems in order to achieve this goal. The recitation time can be used for more interactive activities effectively, such as elaboration of the material and group problem solving.

Purpose

Students not only bring to class their prior understanding of physics concepts, they also bring a set of attitudes, beliefs, and assumption about the nature of physics knowledge, what they are expected to learn, what skills will be required, and what they need to do to succeed. Some of them probably do not develop an actual understanding of physics concepts as a result of traditional types of introductory physics courses. Redish (1997) developed a 34-item Maryland Physics Expectation (MPEX) survey with six clusters to probe students' epistemological beliefs about learning and understanding physics as well as their expectations about the physics course. While the MPEX survey has been used widely by many physics education researchers in the colleges, no single researcher investigated the path based on the nature of gender and the six clusters embedded in the MPEX survey reported.

This study focused on investigating some factors relevant to students' perceptions and performance in learning physics while four specific research questions were generated: Were learning perceptions of students associated with their performance in introductory physics? Were male and female students significantly different on their performance? Were there gender differences in physics learning perceptions? Can educational technology improve physics learning?

Methods

A study was carried out in traditional physics classroom settings that investigated the relationships between student performance in introductory physics, various educational characteristics, learning preferences, and the potential effectiveness of educational technology as a medium of instruction to complement face to face teaching. The survey package consisted of the student consent form along with the three levels of instrumentation which were developed to collect quantitative and qualitative data for this study. It could be administered quickly in the large introductory physics classes.

The first part of the survey forms was designed to gather self-reported background data. In the second part, participants responded to the thirty-four physics learning perception statements that form the foundation of MPEX on a five-point Likert scale from strongly disagree (1) to strongly agree (5). The third part, as a qualitative research method, consisted of four open-ended questions designed to provide participants an opportunity to express their opinions and attitudes in their own words. First, participants were asked about their background in preparation for the introductory physics course they were taking. Second, participants were asked to describe their own experiences on gender issues as they related to physics teaching and learning. Third, participants were asked to give their perceptions of the strategies their instructors used outside of the classroom to help students progress in learning or promote their understanding. Lastly, participants were asked to give their opinions on the effectiveness of applied technology as an instructional aide in helping them learn physics. Technological teaching tools were considered to be one of two types, a tool of instruction presentation (such as PowerPoint used in instructing and/or BlackBoard used to provide problem-solving and tutorial) and a method of communication (such as email or asynchronous discussion line).

The study was conducted with a sample of approximately 450 students who enrolled in four algebra-based and two calculus-based introductory physics classes at the University of North Dakota in the Spring of 2002. Educational technology was integrated into the curriculum in all of the participating classes except one. A total of 267 participants, 161 males and 106 females, participated in the study.

Results

Factor analysis was used to reduce the dimensionality of the thirty-four items of the physics learning perception survey to more basic variables based on the responses received from the participants. Principal component factor extraction with Varimax rotations was used to simplify the resulting factor structures along with maximizing the loadings. Based on the nature of the statement items and Bloom's Taxonomy of the cognitive domains, these six factors were named individually as Physics Learning By Rote (Factor I), Physics Learning By Relating (Factor II), Physics Learning by Comprehension (Factor III), Physics Learning Through Formula Derivations (Factor IV), Physics Learning Through Effort (Factor V), and Physics Learning Through Practice (Factor VI).

Further, the results of the evaluation of the students' performance were based upon their semester long grades on exams and homework assignments. Overall, 70 percent of male and 71 percent of female participants received a final grade of B or higher. No significant performance differences were found between male and female students. However, there were significant gender differences in physics learning perceptions. Female participants tended to try to understand physics materials and relate the physics problems to real world situations while their male counterparts tended to rely on rote learning and equation application. This study found that participants performed better by trying to understand the physics material and relate physics problems to real world situations. Participants who relied on rote learning did not perform well.

It was reported that computer-supported and interactive learning environments better serve the diversity of college students studying introductory physics. Results from the qualitative method at this study showed that a majority of students were on the whole positively inclined to having the pedagogy with the integration of educational technology, such as PowerPoint presentation, visualization, simulation, and found it helpful in learning physics. The results were also positive about advantages gained from the use of BlackBoard and interactive communications such as asynchronous discussion. More than 90% of students in the technology-integrated classrooms reported being benefited by the learning environment while 71% of students in the traditional classroom setting indicated their preference in having the technology-integrated curriculum.

Further, the student performance in the technology-integrated classrooms indicated that 72 percent of the technology-inclined participants compared to 62 percent of the technology-indifferent students received a final grade of B or higher. The student performance in the traditional lecture-format classroom showed that 70 percent of the technology-inclined participants compared to 67 percent of the participants who were satisfied with the current instruction format received a grade of B or better. In this study, however, no significant gender difference was found between students who favored the integration of the educational technology in the introductory physics and students who favored to learn under the traditional instructional format.

Limitations

There are, however, some limitations observed in this study. The number of participants was dependent upon the number of the students attending the class on the day the survey was conducted. The validity of findings of the background characteristics and learning perceptions is dependent upon the accuracy of data provided by the volunteer participants. The research survey was conducted in the classroom in the last month of the semester in order to eliminate the confounding factor of students withdrawing from the classes. Dropouts were not considered in this study, only completers of the course. The variables of the learning environment, teaching format, and instructors have to be controlled. Comparisons between the control group and the experimental group taught by the same instructor were not available.

Discussion and Implication

Many students have the impression that physics is merely a list of formulas to be memorized and recalled at the proper time. Some, but not all, of the physics learning perceptions factors were related, either positively or negatively, with performance in the introductory physics courses. Although all six physics learning perception factors and their interactions are important, significant gender differences observed in three of the learning perceptions factors are of greater importance. A possible explanation is that the learning perceptions, as a whole, may play a very important role in introductory physics learning for all students. The findings suggested that students performed well in the introductory physics depending upon how related the subjects they had prepared in the high school were and subsequently how they perceived physics learning when they were enrolled in the college physics courses. Physics teachers should address the perception and explain learning methods to their students for more effective study.

Tremendous efforts have been made by educators to help students learn introductory physics (Laws, 1991; McDermott, 1993; Redish, 1994). Peer group and collaborative learning have been introduced to the physics classrooms in order to promote communication of ideas and understanding of concepts (Mackin, 1998). Innovative courses using interactive strategies and computer technology have abandoned traditional lectures in an effort to increase student understanding of concepts (Laws, 1991). A wide variety of hands-on physics activities were developed for the students or adapted from existing curricula like Workshop Physics (Laws, 1991) and Physics by Inquiry (McDermott, 1997). More and more educators are using websites as an additional tool to approach their students (homework problems and tutoring) while they utilize computer simulations and new ways of presenting end of the chapter problems (Shapiro, 1997). The recitation time can be used for more interactive activities, such as elaboration of the material and group problem solving (Lindenfield, 2002).

Conclusion

In this study, students performed better in physics courses by trying to understand the physics materials and relate physics problems to the real world situation. The perception of Physics Learning by Rote did not help students learn well or perform better. Overall, gender was not related with performance. The findings of this study therefore delivered some very encouraging information to physics educators. First, male students did not outnumber female students in introductory physics classes. Second, female performed comparably with their male counterparts. Third, female students studied physics by attempting to understand the principles behind the course material while male students tended to memorize the course material. Fourth, 9 out of every 10 students in the technology-integrated classrooms reported being benefited by the learning environment while every 7 out of 10 students in the traditional classroom setting indicated their preference in having the technology integration. Five, a higher percentage of students with the preference for a technology integrated learning environment received a final grade of B or higher compared to the students who did not feel the benefit from the same learning environment.

The main goal in physics training is not only to teach students physics knowledge but also to teach them how to think logically and analytically. A highly effective way to reduce the severity of the problem might be to use warm up questions prior to presenting materials in class. From the answers submitted, the instructor may learn what concepts the students may be missing before proceeds with regular instruction. Perhaps instructors may consider using Blackboard to provide the effectiveness in student–instructor rapid communications. Not only can students easily access lecture notes, homework assignments, answers and solutions for homework assignments, and announcements, it also allows students to ask questions or discuss problems with the instructor with a timely fashion. Many people learn new subjects by seeing or experiencing. Incorporating technology into teaching and laboratory demonstrations could improve the effectiveness of physics instruction and enhance student comprehension and engagement.

Recommendations for Future Research

Collaborative learning, real world application, interaction with instructors, and using technology as tools were perceived by students as helping them learn the concepts of mechanics (Mackin, 1998). Based upon the results of this study, several recommendations for further research were generated. The exploration of the confounding effects related to physics learning perceptions, integration of technology in aiding the student comprehension, and the performance needs to be done to fully understand the features that enhance students learning best and which instructional formats are more potent than others.

References

Bao, L. & Redish, E. (2001). Model analysis: Assessing the dynamics of student learning. Available online at http://www.physics.umd.edu/perg/papers/bao/index.html.

Elby, A. (1999). Another reason that physics students learn by rote. American Journal of Physics Supplement, 67(7), S52-S57.

Foster, T. (2000). The development of students' problem-solving skill from instruction emphasizing qualitative problem-solving. Unpublished doctoral dissertation, University of Minnesota, Twin Cities.

Hammer, D. (1994). Epistemological beliefs in introductory physics. Cognitive and Instruction, 12(2), 151-183.

Laws, P. W. (1991). Calculus based physics without lectures. Physics Today, 44, 24-31.

Lindenfield, P. (2002). Format and content in introductory physics. American Journal of Physics, 70(1):12-13.

Mackin, J. E. (1998). Investigation of selected outcomes of the dynamic physics learning environment: Understanding of mechanism concepts and achievement by male and female. Ph.D. Dissertation, Pennsylvania State University.

McDermott, L. C. (1997). Physics by Inquiry. Wiley: New York.

McDermott, L. C. (1993). How we teach and how students learn-a mismatch. American Journal of Physics, 61, 295-298.

Neuschatz, M., & Alpert, L. (1994). Physics in the high schools II. (R-390). College Park, MD: American Institute of Physics.

Redish, E. F. (1997). Measuring Student Expectations in University Physics: The MPEX Survey. Physics Education Research Group. College Park, MD: University of Maryland. Available online at http://www.physics.umd.edu/perg/expects/aapt97ex.htm.

Redish, E. F. (1994). Implications of cognitive studies in teaching physics. American Journal of Physics, 62, 796-803.

Saul, J., Abbott, D., Parker, G., & Beichner, R. (2000). Can one lab make a difference? Physics Education Research: A supplement to the American Journal of Physics, 68(7 S1), S60-61.

Shapiro, J. (1997). Electronic student response system found feasible in large science lecture hall. Journal of College Science Teaching, 26, 408-412.

Tobias, S. (1990). They're not dumb. They're different: Stalking the second tier. Research Corporation, Tucson, AZ.

Williams, H.T. (1999). Semantics in teaching introductory physics. American Journal of Physics, 67(8), 670-680.