An Exploratory Study to Develop Additional Evaluation Tools for Introductory Physics Courses at WPI

Physics Education IQP-CK-IQ98

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Key Words:

1. Web-based Course Evaluations
2. Physics Introductory Courses
3. First Year Students
4. Student Learning
5. Conceptual Learning

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Abstract

In this project, I will discuss the development of tools to further evaluate the introductory physics classes offered at WPI. These courses are very important to the institution and must be kept at their highest quality. After researching and developing a background in teaching and student learning, a plan of development was set in place, including a pretest survey, midterm survey, and posttest survey. I also recommend the addition of a comment forum built to collect student's comments on teachers. The tools will emphasize student and teacher expectations of each other, relate pretest surveys to midterm surveys, and a strong basis is conceptual understanding of the physical concepts within each respective course.

1 Introduction

A solid and coherent background of physics is required by engineers to understand, conceptualize, and apply the principles of various engineering disciplines studied at Worcester Polytechnic Institute (WPI). A large number of diversified students enroll in the introductory physics courses offered at WPI. This is a typical challenge regularly encountered by an introductory university class, but in this situation they compounded by the pressure to teach the physical concepts covered by these courses in the time allotted. In addition to this, the number of students enrolling in the introductory courses, as well as WPI, has increased every year since 2005. Lecturers have stated the courses were difficult to teach and are only becoming more difficult. Despite these demanding challenges, the WPI Student Course Evaluations (SCEs) have shown support of success since 2005. This seemingly contradictory relationship leads one to wonder a number of questions. Are the SCEs valid when concerning these introductory physics courses? Are the students able to understand and apply the physical concepts and phenomenon studied in the curriculum well? The first two introductory course sets, General Physics and Principles of Physics, will be observed to explore relevant questions, design and create tools to validate the success of the courses, and suggest alternatives to favor student understanding.

2 The Elementary Physics Sequence

The introductory physics courses are contained in a structured sequence, the Elementary Physics Sequence. It is offered in two versions for a number of reasons concerning the diversity of the student body. This includes, but is not limited to, the background level of physics, the background level of mathematics, the wide span of majors, and the relation of physics to the majority of majors at WPI.

There are a number of advantages to the system. The sequences are built as collective building blocks in order to provide the students with a progressively widening and full understanding of physics.

The courses are also suggestively paired with a similar program of a predetermined calculus regiment offered by the Mathematics Department. With this pairing, the lecturers and students of the physics courses are well aware of the mathematics required for each course and the relationship of calculus and physics is emphasized by the juxtaposition. The order and pair of these sequences are highly recommended by the administration, but due to the lack of mandatory prerequisites at WPI, a student may precede in any way he or she chooses. The courses and their respected pairs are shown in Table 1.

General Physics		**Principles of Physics**	
PH 1110: General Physics-Mechanics	MA1021: Calculus I	PH1111: Principles of Physics-Mechanics	MA1023: Calculus III
PH1120: General Physics-Electricity and Magnetism	MA1022: Calculus II	PH1121: Principles of Physics-Electricity and Magnetism	MA1024: Calculus IV
PH1130: Introduction to 20th Century Physics	MA1023: Calculus III	PH1130: Introduction to 20th Century Physics	MA2051: Differential Equations
PH1140: Oscillations and Waves	MA1024: Calculus IV	PH1140: Oscillations and Waves	MA2071: Matrices and Linear Algebra I

Table 1: The Elementary Physics Sequence.

General Physics and Principles of Physics are similar in curriculum. What separates the two is the expectations of the student body in their respective versions. Both versions are calculus based, but General Physics only applies calculus conceptions and students are not expected to apply derivatives until PH1120 or integration until PH1130. This version is generally for non-physics majors.

Intended for students with heavy backgrounds in science and mathematics, one may enroll in Principles of Physics for a stronger background of the material covered. They are also expected to differentiate and integrate elementary trigonometric and polynomial functions, and be able to graphically interpret these operations. There are some additional topics presented in Principles of Physics. PH1110 and PH1111 are generally taken by students during A-term their first year, followed by PH1120 and PH1121 in B-term.

2.1 General Physics

The General Physics section is very large and is split up into two lecture sections. The A-term 2010 PH1110 class had just over 400 students registered and the B-term 2010 PH1120 class had 367 registered. There can be up to 30 students in a single conference or laboratory session as well. The lecturers are not always the same year to year, but there has always been one common lecturer between consecutive years since 2005. One on one learning is rare, but is obtainable during office hours or a private appointment with a lecturer, conference instructor, or lab assistant. There are a number of other resources for students if they need more one on one help such as MASH or other students in the Physics Lounge.

The class is rigid, fast-paced, and is a large time commitment for students and teachers. A single topic is generally taught in a single one hour lecture. The lecture is three times a week and alternates days with conference. Conference typically includes numerical examples and question and answer sessions, but the instructor may do as he or she wishes. Laboratory sessions are held once a week and students are assigned a lab report discussing the physical concepts displayed by the lab.

From the amount of work mentioned above, it is obvious to say homework has become an essential part of the General Physics sequence. The amount of homework generated is quite large and students are warned about this directly. It is very difficult to catch up after falling behind due to the momentum of the course.

Homework is given to students in a three forms: written homework, Mastering Physics homework, and summery homework. Written homework is due at almost every lecture and consists of topics pertaining to recent lectures. Mastering Physics homework is assigned two to three times a week. It is completed and graded online; students receive immediate feedback. The summary homework was added to the course in 2007. Four summary homeworks supplement the four study guides created by the lecturers, and they are due before the day of their respective exam. This homework is to better prepare students for exams by summarizing the material on the tests. The study guides provide a list of topics pertaining to the questions and provide a suggested study procedure. In addition to the homework, lab reports are assigned after each laboratory session and all of these reports are required to pass the course. These reports tend to be fairly easy and can be quickly completed.

2.2 Principles of Physics

Principles of Physics holds a different weight. Even though a majority of the topics and requirements are similar to General Physics, the context in which students explore the physical concepts and phenomenons are quite different. Students are expect to be comfortable with calculus based mathematics and must employ their skills frequently. They are also compelled to apply conceptual learning because of the high caliber of questions asked of them in such high volumes. There is generally one common topic covered in lecture as in General Physics, but situations concerning conceptual applications are examined more thoroughly.

A major difference of Principles of Physics could be a result of the teaching style chosen by the lecturer since 2006. Students are asked to complete a moderate amount of group work. Lectures are not exclusively traditional lectures, but occasionally are group based. Students are asked to complete interactive sets in conference. This type of work is group based and must be handed in at the end of the conference. An end term project is assigned to groups of 2 or 3 as a capstone to the course. The project is very general to where groups pick any topic included in the curriculum. A group must complete a 2 page report discussing their topic and produce a 15 minute presentation for the class with a question and answer session. The presentations are treated as a reward for completing the class by creating a relaxed environment for the students after the third and final exam.

2.3 Difficulties of Teaching the Sequence

There are a number of influences which cause teaching difficulties in the introductory sequence, the most difficult and complex factor being the wide variety of students. The introductory courses are attended by students of all majors, which present a large amount of material to cover. To cause more problems, the number of students enrolled in the General Physics courses has been over 350 students each year, since 2005. In addition to these trying aspects, there exists a large burden of ensuring this large number of students are capable of understanding and applying the concepts developed in the course. Since the workload of the teachers is already so great and the time constraints are always looming, teachers tend to focus on applying the concepts. Understandably, the students need to learn how to teach themselves the conceptual design they are applying, however this may be a source of more problems due to differing expectations of the students and teachers.

Another difficult characteristic of the introductory course is the fact that most of the students are first year students and many have not experienced this type of intense study. The new students may also have preconceived and/or incorrect concepts of physics from their past experiences. This can be a challenge to overcome, but it is essential to grasp the true nature of the concepts based in physics (Halloun and Hestenes 1985). There is always the possible that these courses are the only physics courses certain students take. This only adds the seriousness in which they must learn to understand the physical concepts and not be able to only apply the laws in a “recursive plug and chug” method (Torigoe and Gladding 2010).

3 Dimensions of Student Learning

With the exerted importance of teaching a solid foundation of physics with concepts as well as numerical examples, student learning is at the forefront of course priorities. Student learning in these physic introductory courses has a substantial number of dimensions relating to the mainly first year students.

3.1 Evaluations of Understanding

There are a number of reliable and valid ways of measure the conceptual understanding of physics by students. Some of these include the Force Concept Inventory (FCI) (Hestenes, Wells, Swackhamer 1992) and the Force and Motion Conceptual Evaluation (FMCE) (Thornton 1997). Both of these evaluation tests are well posed, reliable, and valid. They consist of a pretest and a posttest. The material are made of well-established beliefs and the results of the tests are independent of the instructor and way of instruction. The tests are calculus based, posing a problem for use in the entire introductory course program. Never the less, they are great tools to understand the preconceptions and incorrect beliefs of the student body. They can be administered quickly and efficiently.

3.2 Teach to Learn

> "We submit that the primary objective of introductory physics instruction should be to facilitate a transformation in the student's mode of thinking from this initial common sense knowledge state to the final Newtonian knowledge state of a physicist"
>
> -Halloun and Hesten (1985)

This should be one of the most important subjects of teaching in general. The transformation mentioned in the above excerpt is the reason for attending higher education. Students should be aiming to change the way they can think as well as practice education techniques on themselves.

4 The Tools

4.1 Pre-Term Survey

This would be one of the most powerful tools developed by this project. This survey has a multitude of levels in which one can interpret such data. A study done by Prosser, Walker, and Millar concerning the perceptive differences in learning physics states this an important factor to watch with respect to the teachers evaluations..

4.2 Mid-Term Survey

A mid-term survey would be very helpful to teachers. With information concerning how the students feel they are doing and reactions to teaching techniques, the lecturer may decide to change or continue any teaching technique at the request of the students.

4.3 Post-Term Survey

The post-term survey must be administered to grasp how well the students expected they did. This survey must be administered before the final exam to ensure the best measurement of their expectations and assumptions of understanding.

4.4 A Comment Page

This was another IQP completed by Fenner, Gould, and Heald (2000). The scope of the project was to test a forum type community for students to directly comment on teachers and their ability. This was of course done anonymously and online. The information was collected over time and students and teachers were able to access the site at any time. For the most part, the project was found successful; however, it was never implemented to a universal level. Reactions from students and teacher were better than originally thought to be and all parties were content with the website. There was one issue of validity that would affect the implementation into this project. A forum type community would require censorship of nasty and unproductive comment. This would be difficult to apply as well as maintain. (Fenner, Gould, Heald 2000)

5 What are the goals of these tools

If properly developed for the intended audience, the tools built should help provide more stable flow of information between the student and teacher concerning the following dimensions of mastery of physical concepts and phenomena by the students: background of the student, preconceptions of the students, and measureable and understandable feedback of data. An instructor should have the ability to view the product of the tools to more objectively define changes or continuations of current teaching practices during and after the course.

We need to ensure an understanding of the course concepts in the students. For many students, this is their only experience in an academic environment which focuses on the physical concepts they must understand to appropriately apply physical law to their major and throughout their professional career.

Self-evaluation and self-revelation are important vehicles in which these tools use. The teacher will receive understandable evidence which is specific to that year's class and students will receive actually comparisons of reality and their expectations of themselves. With proper book keeping and understanding of the concepts portrayed in this project, the introductory physics courses will still be large, but the teachers will be able to specify their teaching methods for as many people as possible as the students tweak their study habits. This supporting claim can be measured by the post-term survey expectations of the students.

Another major goal of this project is to try and find a balance in expectations of the teachers and of the students. Concurrently, the teachers should use these tools to ensure a holistic view of physics is being properly conveyed to the students. A long term goal is to measure the long term effects of the goal of conceptual learning. One may do so by administering another FCI or FMCE test in the semi-distant future.

6 Validity issues

One of the most prominent validity issues is the fact the tools developed were not tested. Two of the tools were tested while in a prototype phase. This preemptive run was necessary to collect some basic information of the students and teachers, but they were not tested for their relevance to reality. The tools developed clearly need to be tested before the scope of the project, a better measurement of the amount learned by students in a conceptual form. I would recommend testing the validity of each tool before a comprehensive study on the validity of the wanted effect of the tools.

The student surveys are to be based on the web. This can present problems such as low response rates, but the monetary effectiveness achieved by a web survey is necessary. There are some ways to improve the errors within website surveys: coverage error, sampling error, and nonresponse error. Coverage error and sampling error are fairly self-explanatory, how much of the community did you cover and how valid is your sample of the community? An easy fix to these problems is to survey the whole class. Ideally, I would want these tools used in a mandatory setting, but I find that would be too difficult to achieve and I would be worried about additions errors due to the unwillingness of the students or teachers. Nonresponse errors are more difficult to correct for, but there are tips and tricks to making web surveys more available.

I am quite worried about implementing these tools to both introductory sequences. They are built to be different from each other are are in many ways that can affect the power of these tools. The dependence of mathematics in Principles of Physics is only a single issue. The epistemology of the students could be astounding. Their differences in background and experience are always going to be a point of validity to worry about.

7 Work Cited

Hestences D, Wells M, Swackhamer G. 1992. Force Concept Inventory. The Physics Teacher. (30): pg 141-158

Halloun I and Hestenes D. 1985. The Initial Knowledge State of College Physic s Students. American Journal of Physics 53(11): pg 1043-1055

Prosser M, Walker P, Milar R. 1996. Difference in Students' Perceptions of Learning Physics. Physics Education 31(43)

Fenner M, Gould J, Heald J. 2000. Improved Teaching Evaluations. WPI IQP. Project PWD-4393

Torigoe E, Gladding G. 2010. Connecting Symbolic Difficulties with Failure in Physics. Americal Jounrnol of Physics. 79(1): pg 133-140

Thornton R. 1997. Assessing Student learning of Newton's laws. American Journol of Physics. 66(4): pg 338-352