AC 2011-2293: UTILIZING PEN-BASED WIRELESS DEVICES IN PHYSICS CLASSROOMS

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Utilizing pen-based wireless devices in science and engineering classrooms

One of the major challenges facing science and engineering classrooms today is the students' dwindling interest in the basic sciences. The joy of learning fundamental scientific principles is eclipsed by the excitement of modern technology and the ultimate quest for a rewarding employment. As a result, the number of basic science majors, for example in physics, has decreased significantly over the past decade[1]. Today, only a small number of engineering students study physics either as a second major or at an advanced level in institutions of higher education, such as Rose-Hulman Institute of Technology (RHIT). Engineering technology students in general at Southeastern Louisiana University (SELU) also lack sufficient knowledge of physics, and their performance in classes such as Engineering Statics often suffers as a result.

With these challenges in perspective, an effort is being made to encourage student interest so that they (a) can discover how to apply physics principles in real-world situations, and thus enhance their background for an engineering/technology discipline, and (b) can be retained in the physics department at RHIT, with physics either as a first or a second major. This paper describes how experiments have been taken outside of the laboratory and into real word situations for a few specific courses. Two are freshman physics courses at RHIT, and the others are engineering mechanics courses at SELU. The experience gained from this initial effort will be used to expand the scope of this effort to other physics courses in RHIT and to other physics-oriented courses in the Engineering Technology program at SELU.

Expand the boundaries of the laboratory classrooms

We have incorporated a number of experiments in solid mechanics, which are to be performed outside of the laboratory rooms, and in a real-world setting. The expectation is that if a considerable portion of fundamental physics principles could be taught outside of the contrived laboratory setting, the students would be more likely to relate to the relevance of them in the outside world. Engineering majors taking the freshman physics sequence should be particularly excited, as they have a tendency to be drawn to tangible, practical examples. Once the students feel comfortable with the underlying scientific principles, they will find it easier to incorporate various perturbation factors that may come into play in different real-world situations.

In this context, we also explore the recent trend[2,3] in many universities for an increased reliance on wireless technology that has enabled users to enjoy and exploit the freedom that was unknown a decade ago. For example, tablet computers are being widely used for wireless delivery of course content. These tablets can be wirelessly connected to a network, but unlike many laptop computers, the tablets weight much less, can be moved around safely with the hard-drive on, and have note-taking features. Such devices are capable of significantly expanding the frontiers of traditional classroom and laboratory spaces. One wireless technology being used in the classroom in order to make the learning experience more effective is DyKnow[4].

Background

RHIT is primarily an undergraduate engineering institution, and the greater part of the student body (about 1800) majors in various engineering disciplines. RHIT offers excellent education in engineering, science, and mathematics, and for the past several years, it has been ranked as the best undergraduate engineering college in the nation[5]. The Engineering Technology (ET) program at SELU is relatively new in comparison, and is part of the Department of Computer Science and Industrial Technology. The department attracts about 650 students, of which approximately 100 students are enrolled in the ET program. ET students from the Mechanical and Industrial Engineering concentrations take the sophomore level Engineering Statics course.

Students embarking on a university education in science and engineering have, in general, a modest exposure to the basic principles of physics. It is therefore imperative that these students understand and appreciate the importance of physics principles at the freshman and sophomore levels. It is only *after* the freshmen/sophomore years that they are likely to realize the importance of physics in their applied engineering courses, and thus feel encouraged in taking additional courses. Furthermore, it seems that computer technology is not currently utilized to its fullest potential of making classes more interactive and exciting, and data acquisition easier. There is a noticeable lack of interest among students for using their laptops for learning purposes, unless required for a particular experiment.

At RHIT, the Physics Department was the first to incorporate the "studio" style of teaching in the Spring Quarter of 1997-98. This teaching concept was introduced earlier by Professor Jack Wilson[6] at Rensselaer Polytechnic Institute (RPI) and has since been implemented in many institutions[6-10]. In this format, the teacher spends less time at the blackboard, and the lectures are broken up by mini-experiments. The separate lecture/laboratory format of teaching is eliminated. At RHIT it was found that the students under this new format outscored those in the traditional method by 15% in the final examination, even after the examination was independently graded by three different instructors, thus proving that this teaching method to be superior. However, one limitation is that on-the-spot data analysis outside the classroom is not possible with the existing laptops.

This first attempt in using this new style of teaching at RHIT prompted the Physics Department to launch more pilot programs[11], and was adapted only in the smaller "trailer" classes. Although the overall student feedback for the studio classes is positive[10-11], the improvement is not extraordinary, and some students still do not become excited about the topics taught in these courses.

In Spring 2003 and Spring 2004, eight faculty members from RHIT, including one of the co-authors, Sudipa Mitra-Kirtley (SMK), received two grants of $220,500 and $130,500 from Hewlett Packard. The funding was used to purchase several wireless computing devices. The goal was to accelerate the making of a "campus of the future", by creating test beds for mobile technology solutions within various disciplines.

This paper describes a few hands-on learning activities that aim to engage the student in learning key scientific concepts in a real-world setting, using wireless technology wherever needed. It is expected that the students are more likely to retain the learning material successfully, and develop a positive experience about the subject matter. It is hoped that these activities will ensure that the monotony of taking lecture notes and the boredom it creates are reduced.

The primary goals are:

- Break away from the laboratory confines and make the experiments directly relate to the outside world. Wireless technology will be an integral part of this.
- Introduce many additional stimulating and challenging activities *or student projects* that will modeled after real-world situations in the laboratory

- Initiate interactive pedagogical methods to increase class participation, and effective student-teacher communication.

Implementation of new ideas

The concept of centripetal acceleration is often not understood properly, and students often confuse the pseudo centrifugal force as being a real force from their experience in automobiles. In the Physics I class at RHIT, the students use the Sports Center to collect the centripetal acceleration data. They run around a semi-circular track at a constant pace, and use Vernier Software Technology's Logger Pro software to collect data. First the students are asked to gauge the radius of the track using their own measurement technique. Next an accelerometer is pinned on their chests, and they set up the Logger Pro hardware so that data may be collected remotely. One partner then runs around the track at a constant pace, and the other supervises the procedure. At the end of the run, the first student unloads the data collected on the un-tethered tablet, and the procedure is repeated several times till the data looks acceptable (which may mean that the acceleration vs time graphs look very stable). The two partners then analyze the centripetal acceleration from the collected data, and investigate if the collected data matches the theoretical formula. The collection of the data on the spot allows them to realize the concept of centripetal acceleration in a practical setting, and be aware of possible perturbations that may arise in real-world situations. Every time this experiment has been performed, students are always excited with the confirmation of experimental data with the theory. Comments such as "I could actually feel the existence of centripetal force" have been common. Understandably, after this simple exercise they have a better understanding of inertia, and why that fact may lead them to, erroneously, believe in the existence of centrifugal force.

Another idea that is implemented in Physics III, the third course in the introductory physics sequence at RHIT, is an activity investigating the Law of Malus. The Law states that the intensity of the transmitted light through a polarizer varies as the square of the cosine of the angle between the incident and the transmitted polarization directions. Students here are asked to gather data outdoors on a sunny day. They bring with them a small kit consisting of a couple of polarizers, a solar detector, and a tablet computer. They measure the incident intensity, and then slowly vary the angle of a polarizer to measure the corresponding transmitted intensities. They graph the data on the spot, and compare the plot with the predicted plot using the Law of Malus. If they use the tablets near the buildings, they are still privy to the wireless feature of all the buildings, and they compare their data with that from other groups from the same class who are performing the same experiment elsewhere on the campus. The students have always enjoyed this experiment, and they are seldom found to make mistakes on related test problems. Again, doing this in a real-world setting makes them more aware of the perturbations that may creep in such situations, such as what happens when a cloud drift in front of the sun, etc. It is interesting to see how the students account for such changes and consequently come up changes in experimental procedures. I have heard students mention that they are now more aware of the polarization aspect of light, and how the textbook makes a "lot more sense" with this experiment.

At SELU, Rana Mitra (RM) is planning on taking the Engineering Statics students to the campus gymnasium. In one experiment, the students will carry out an activity with a simple set-up consisting of a rod hinged at one end. Weights will be hung from the free end, and a force sensor will be attached to the top of the free end to measure the force that is needed to hold the rod at a certain fixed angle. For the same hanging weight, the angles will be varied, and consequent measurements will be made from the force sensor. The set-up is illustrated in Figure I. A pair of students will take two sets of measurements, and the data will be averaged. A plot of the force sensor reading will be made as a function of the angle. In the second part of this experiment, the hanging weight will be varied while keeping the angle the same. Just after this the students will experiment lifting a weight with their forearms, bent at the elbows. The students will see how the pressure on the arm varies as the angle is changed for the same weight. Are they "feeling" the same results as their plots dictate? What will happen if they use their entire arm lengths instead of the just their forearms? Is it easier to hold the weights at a greater angle from the horizontal? Can this be explained by the "resistive term" of the moment of inertia of the arm about the pivot point?

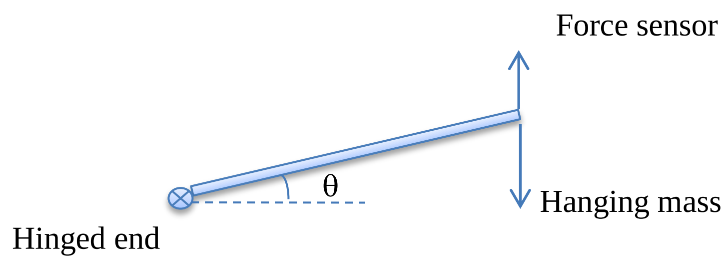

Figure 1. A model of a static equilibrium situation

Another experiment that is being developed at SELU involves the leg as the movable "arm". The same models will be used, but now the students will be experimenting by lifting weights with their legs instead of their arms. How will the situation change and what are the reasons for such changes? The advantage of collecting data at the gym will not only have the students relate to real-world systems in statics, but will also make them realize the implications of changes in the theories when physical situations deviate from the ideal situations. The prospect of experimenting with set-ups from every-days lives is very powerful and for this reason the material will be probably retained more effectively.

A third example that RM is working on is the apparent weightlessness of students in elevators. This will be a very simple but intuitive experiment based on the principles of Newton's Second Law. The equipment will consist of a force plate, and a LabPro interface. The students will bring the equipment inside an elevator, and as the elevator will move up (or down) to different floors, LabPro will acquire data from the force plate. The students can then analyze the force-time data, and will be asked to generate simple free-body diagrams, and the actual acceleration of the elevator. They will be able to compare the results with other groups doing the same experiment, across the campus, via network connections. The added bonus of the tablet is that it can be carried along while the hard-drive is on, is easy to carry, and does not need wires to connect to the network.

In RHIT, DyKnow software package has been used for several years now in a number of different disciplines. SMK introduced this idea first in the physics classes at RHIT. There is an enormous potential of these wireless prospects, especially by opening up experimental opportunities in real-world settings. A software package, developed by DyKnow Inc.[6] for wireless devices, lets students ask questions, answer quizzes, and give feedback to the instructor, while remaining anonymous to the rest of the class. The instructor can write notes on the tablet screen (which can be projected on the classroom screen) and the students can add their own notes to these class notes, and the whole package can be saved on the DyKnow network. The students can retrieve these notes from anywhere, as long as internet connection is available at the site. In spring 2004 this was tested in one section of the second introductory physics class for two weeks, and most of the students enjoyed the experience. The combination of wireless tablets and DyKnow can be made extremely effective both for in-class and out-of-class learning in the future. One of the co-authors (RM) is investigating the idea of incorporating wireless tablets with DyKnow at SELU, making both the lecture and laboratory sessions more effective.

Experience with DyKnow has shown that academically weaker students now participate actively in class discussions, and in general, have improved their performance. Frequently during class student feedback on understanding a particular topic is gathered anonymously. Paperless quizzes are collected and graded using this software. Often a student work is displayed anonymously to the entire class, and the instructor reviews the work and singles out the mistakes in the submitted work, so that the rest of the students are also aware of avoiding similar mistakes. Sometimes the instructor asks students to identify real world examples gathered from the internet, which is then embedded in the class notes for future references. One such example used by SMK was finding out characteristics on solar sails, from the internet, as an example of pressure exerted by electromagnetic radiation. The point is that wireless technology used in the classroom to understand real-world applications of physics principles is extremely powerful, and very promising.

Similar ideas elsewhere

Our project idea is new as it combines the “studio” format of teaching and the idea of bringing the experiments outside of the classroom using wireless technology. If looked at separately, the “studio” idea and the wireless opportunities are known and practiced in many campuses. There are many examples where different aspects of remodeling introductory physics have been implemented to attract and retain more students. RPI, North Carolina State University, Massachusetts Institute of Technology, and University of Oregon (UO) are some examples where interactive “studio” physics has been successful[13]. Lawrence University (LU), College of the Holy Cross (HC), and State University of New York, Stony Brook[14], have included physics activities based on one’s daily life. HC has increased student enrollment considerably by using interactive courses and by revising the curriculum. LU and UO use computer technology exhaustively in their physics laboratories. All the above examples show success in student learning with the new methodologies. Student feedback from our own pilot effort of “studio” classes also shows an overall, although not significantly, positive student feedback..

There are already innumerable campuses across this nation and elsewhere where wireless technology is part of the computing setup. Of the many such institutions, only a few are mentioned here: Harvard University, Case Western University, Carnegie-Mellon University, College of William and Mary, Universities of Colorado, Michigan, Wisconsin, Dartmouth, Kentucky, Pittsburgh, DePauw, and California, Los Angeles. Some of the other recipients of the HP grant, such as Georgia Institute of Technology, Oregon State University, Purdue University, and University of Texas, Austin[15], also attempt to incorporate wireless technology in their education.

According to the Strategic Programs for Innovations in Undergraduate Physics (Spin-Up) project sponsored by the American Association of Physics Teachers (AAPT), the American Physical Society (APS), and the American Institute of Physics (AIP)[16] , successful physics departments employ a variety of different strategies[1]. Our proposed teaching methodology will bring about much needed enthusiasm and curiosity in learning physics, especially for engineering and technology majors. It will also help many students who lack the skill of working in groups to improve their ability to work in teams and thus benefit them in their future careers[17].

Assessment

The Office of Institutional Research, Planning and Assessment (IRPA) at RHIT has been working closely with SMK to implement assessments of the more interactive physics courses. Some focus groups with students have fathomed the students' feedback on the new teaching methodologies. At the moment, some qualitative data have been collected, and work is still being done to device ways in capturing quantitative data which will only single out the effectiveness of the new methodologies. Some of the students' comments are captured below.

Some of the positive comments on the laboratories integrated closely with the lectures, and on the use of wireless tablets with DyKnow software are:

→ This class is awesome, everyone should take it
→ The small hands-on labs were my favorite part of the course
→ I am not failing physics
→ Made it easier to recall material
→ I felt like dyno was the the best way to convey the information.
→ i liked using dyknow and felt it was a good way to have the class follow the instructor
→ it explains a lot about how the world around us works
→ The dyknow notes seem to be very helpful
→ The labs helped me understand the material better.
→ using dyknow for taking notes and being able to save and review them
→ I really enjoyed most of the labs.
→ This course actually had useful labs that pertained to the material.
→ DyKnow is an effective teaching tool.
→ I thought that one of the biggest strengths of the course was being able to do in class exercises where we were able to discover the principles behind the stuff we had just learned
→ Studio Physics having the lab as a part of the class makes the material flow more smoothly.
→ The only positive outcome of the Dyknow interface was that we could save the exact work from the teacher for use later, incase i fell asleep during class or neglected to take notes during a certain part.

Some of the negative comments from students include:

→ No more use to tablets. They are a very distracting.
→ More instructions on the lab
→ The course could be improved by making each class of physics more standardized. For example, I wish all of the courses did the exact same material at the same time. I say this because it would be helpful to work with other individuals on the same type of material
→ I think you should incorporate how our status is (on DYKNOW) all the way through your class. This tells you if we really have a question or not.
→ Less lab reports that are graded so harshly. Instead have more activities that are short and not as hard to write up.

Next stage

In the future a more exhaustive assessment plan is to be incorporated so that quantitative data can be gathered which addresses specifically the effectiveness of the real-world based labs and the use of wireless tablets with software packages, such as DyKnow. At SELU the use of DyKnow will be implemented this academic year on a pilot scale. One of the authors (RM) is working on the Assessment subcommittee for the Engineering Technology program, and will be directly involved in gathering the students' pre- and post-concept inventory tests on a regular basis for Engineering Statics. Focus groups and student surveys will also be employed which will capture some of the qualitative feedback from students.

Both the authors wish to expand these ideas further in the future in several different courses, such as Engineering Dynamics in SELU and Many Particle Physics in RHIT. The number of experiments that pertain to the real world will be increased. More efficient usage of computer technology to gather data will be planned so that the time spent in doing the experiments does not extend beyond a two-hour block. More assessment data from the students will be collected. In RHIT some students are still not comfortable with using software packages, such as DyKnow, with the tablet computers. Careful evaluation of student feedback and course evaluations will be performed so that the students end up with a positive experience about the course material. The goal in both the academic institutes is to make basic physics principles more exciting and more related to our everyday lives.

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