University Physics II - Class Design

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Chapter 1

Introduction

Before we became educational researchers and designers, we were parents and students who had many unpleasant personal experiences with educational reform and educational systems. Our eldest daughter experienced a social studies enrichment, called the Mini-Society, at two different schools. The Mini-Society has become our model for an educational reform based on a very good idea that does not achieve the desired results. In the first school, in the hands of a master teacher, the Mini-Society was a marvellous experience, but probably not as educationally effective as the normal curriculum. In the second school, because of local implementation decisions by the teacher the Mini-Society had no educational value while occupying large amounts of class time. Further the second experience was not even motivational for the eldest child. Our youngest child also experienced the Mini-Society, for her it was a very motivational experience, but still one that did not teach any of the economic lessons it was designed to teach. The Mini-Society is being slowly abandoned by our local school. From this and other experiences, we learned set lessons from being the objects, not the instigators, of educational reform.

- An educational reform replaces traditional instruction, the gain of the reform must be measured against the loss of traditional instruction. The Mini-Society fails primarily because it replaces traditional classroom activities with activities of lower educational value. A reform should not be broadly distributed until a controlled test against traditional instruction is performed. Note this requirement has not been met by the PER community. We hope to make the first quantitative measurement of an educational reform against the class it replaces this fall.

- The student-to-student stability of an educational reform is also important. The Mini-Society has greatly different motivational effects on children drawn from the same family. A more reliable educational experience must have precedence over less reliable experiences. It should be noted that Richard Hake's data shows strong instabilities in the interactive engagement reforms.

- The Mini-Society innovation failed partially because the local implementation decisions of the teacher changed the educational value of the course. The training the teacher received was inadequate to allow her to make decisions about how to specialize the reform to her classroom and student population. Instructors modify classes to fit their classroom and style. A successful reform must guide this modification so the educational value of the reform is not lost.

- The Mini-Society does not provide feedback in the form of evaluation and is not integrated into the normal curriculum. Integration and quantitative feedback are crucial, so that the reform appears part of the normal body of knowledge to be mastered, so that the student applies normal study skills to the topic, and so that the instructor see tangible effects from their efforts.

- Cost Matters. The Mini-Society was very low cost, but many other reforms, particularly in science teaching have large relative costs. A high cost reform that is functioning inefficiently is likely to be abandoned before it can be optimized.

Chapter 2

Requirements for a Successful Educational Reform

With the Mini-Society and other bad experiences with innovative education in mind, a set of criteria that a college science class that contained reform elements must meet to achieve broad acceptance outside of the education reform community was developed. We have made great strides toward that goal in UPII but much work is still to be done.

1. **The reform must lower the instructor's workload while increasing student performance.** This one is obvious. While a reform environment, governmental pressure, and individual educational zeal may advance reform in the short term, long-term changes must succeed in the marketplace. Traditional education is strongly optimized to minimize the lead instructor's time commitment. To replace traditional instruction, an innovation must lead to no more or lower time commitment than traditional instruction. I know of no instructor who is a candidate to implement reform who is not already working as hard as they possibly can. As with any innovation, educational reform must work better at a lower cost to make broad inroads into education. It must work better to overcome the increased training and equipment costs. Primarily is must lower instructor time commitment while producing a superior product to attract instructors that wish to do a good job, but may not wish to commit the fantastic amount of extra time a great job often entails.

2. **The instructor must be allowed to innovate.** Education is dreadfully unpleasant if an instructor cannot make changes to a course when they have a good idea.

3. **The innovation must be managed.** The Mini-Society's educational value was destroyed by innovation, so the innovation must be controlled. We see this happening in two ways; (1) Tools for the instructor to characterize their innovation and see the global effect on the course and (2) A strong education substructure, reading, homework, and activities that minimize the effect of poor innovation.

4. **A full design must be specified.** Before a class can be improved, one must say specifically what it is supposed to do. At present, the level of design for a physics class is a paragraph long list of section titles. At this level of design all classes succeed, the students learn something, and all classes fail, the students don't learn everything. A much more specific design is required before one can say whether a course is working.

5. **Deep Testing.** The class must be deeply evaluated by a variety of instruments. Based on their response to the FCI measurement, there is a substantial minority, perhaps majority of physicists, that are not going to make changes in methods they believe work for a single standardized test. It is not necessary to test the students beyond what is already being applied, simply to use all evaluations of the course to construct a complete picture of the student's conceptual and non-conceptual gain. This is fully implemented in UPII, however the results will need the information modelling for interpretation.

The Spring 2004 implementation of UPII achieves a neutral time commitment, a full design, and deep testing. Additional development is required to allow instructors at other institutions to innovate and to model their innovations.

Chapter 3

History

In 1994, the University of Arkansas received a grant from the National Science Foundation to revise its introductory physics program. University Physics II(UPII) is the product of that revision and subsequent fine tuning. The class has advanced through a series of stages.

Pre-History Before 19945, University Physics II was a traditional lab/lecture course taught out of Tipler and assigning problems out of Tipler. The lab presented 10 experiments a semester. The class was profoundly disliked by students. Much of the motivation for reform came from a need to field a class that resulted in fewer student complaints.

Stage I: Fully Interactive Lab-Based Class Upon receiving the position at Arkansas, Dr. Gay Stewart revised the traditional course into a course taught exclusively in a laboratory setting with about 30 students per lab. Interactive Engagement activities were introduced. This format worked well for some instructors. Some however had difficulties connecting to the students in this setting. This stage introduced the key innovation of twice-a-week, two-hour laboratories. This modification greatly increased the amount of low student/teacher ratio time available to the class.

Stage II: Modified Traditional The fully interactive laboratory setting required either full faculty or exceptionally expert graduate student teachers for success. The format was therefore too resource-intensive for long term use. In the next stage, the interactive labs were retained, but a twice-a-week 50 minute lecture was implemented. This allowed the labs to be staffed with teaching assistants (TAs), with the lead instructor taking the first lab. The second key management innovation was introduced at this stage. New TAs were required to help in the instructor's lab section so that they saw an expert present the material and were fully prepared to teach their sections. This provides a level of teaching instruction for the TA far beyond the normal week-long TA preparation program.

Stage III (Current): Stable Modified Traditional The modified traditional course required constant fine tuning by the lead instructor (Gay Stewart). It was often sensitive to the background of the TA. It also suffered from the lack of support of Tipler for some of the interactive ideas in lab. To solve these problems, the lab time was fully scripted into a set of activities. A set of course readings were produced that better fit the lab and had more conceptual content. At this time Dr. John Stewart took over as lead instructor and Dr. Gay Stewart began modifying the mechanics course UPI. This stage is now complete and its result is the material at this site.

Stage IV: Fully Characterized Class Software and modelling structures are under development to form a detailed model of the entire UPII course including homework and test problems, lecture, and lab instructional models. Once characterized by this modelling system, the question of how much is being taught, what is being taught effectively, and what types educational interactions are most effective can be answered. Early experiments on computer-aided class design show that these modelling structures are the correct structures to allow the automation of the design process. At the end of this stage we will produce the most carefully understood educational system in history. This stage should be complete by the end of the Fall 2004 semester.

Stage V: Reconfigurable Class The class produced by the previous stage is profoundly well-characterized but static. To maintain the careful timing in the class an instructor must present the class without change. This violates the requirement that an instructor innovate and make coverage decisions. Further, it does not allow for local differences in lab facilities and equipment. This stage will take our existing material base, already divided into a highly modular set of computer readable files, and provide software that allows an instructor to design his or her class guided by the modelling structures produced in the previous stage. Since software already exists to allow our construction of new objects, there is no fundamental reason why an instructor at an adopting institution could not write his or her own additional materials that would be seamlessly integrated into the course materials. At the completion of this stage, UPII will meet all requirements for an educational reform to achieve full adoption.

Chapter 4

Class Design Philosophy

UPII grew out of experience of Dr. John and Gay Stewart with introductory science classes at large and small institutions as they received their degrees. This experience was combined with current research into physics education and the resources of the University of Arkansas to produce the first iteration of the course. The current course grew out of experience drawn from the teaching of UPII over the last ten years.

4.1 Inquiry

Student learn and retain best when they build knowledge by personal unstructured investigation. You know it best if you found it out yourself. As much as possible, students are allowed to explore, theorize, and challenge their theory. Experiments are open using common materials so students can innovate. Demonstrations are brought into the lab so students can try it themselves. This has generated a marvellous and fun lab environment and probably the fastest growing undergraduate physics program in the country(world?).

4.2 Structure and Timing

Class policy is based on the principle that you should do the obvious stuff first. If a car has no tires, fine tuning the carburetor will not improve performance. UPII presents less lecture and more lab, 2 hours lecture and 4 hours lab, instead of three hours of each. This is the minimum amount of lecture the students feel comfortable with. Policy to insure near 100% lab and lecture attendance is in place. The class is carefully timed so that lab and lecture complement each other.

4.3 Dedicated Reading

To maintain timing, but still allow the lecturer the freedom to take questions and discuss events of interest, the reading for the course must contain the material the student needs. A dedicate class reading is included that has all the required material and a set of very detailed examples. The course reading also contains additional conceptual information to support the laboratory.

4.4 Thematic Design

Most introductory physics labs are based on prepackaged experiments. Having presented these at various institutions, we believe that the prepackaged nature separated the students from the phenomena they were studying. The students punch buttons and connect wires, but do not experience the physics. Furthermore, the labs are expensive and cannot be replicated by the student; either in the role of teacher or parent. As much as possible, we have used homemade equipment and commonly available instruments such as voltmeters in our lab. The accuracy has been comparable to the commercial labs (often better) at a fraction of the cost. This has had the additional benefit that our labs are easily usable with some conversion by K-12 teachers.

The non-prepackaged labs and demonstrations have also allowed the introduction of fun into the lab, where the students build motors and speakers and we shoot coil and rail guns. We routinely have requests by schools and children's organizations to present activities from the lab, an excellent sign for long term retention and penetration into the K-12 curriculum. All activities however are wrapped around the correct physical description of the device or phenomena. No time is lost.

4.5 TA Training and Preparation

An interactive class depends crucially on the preparation of the teaching assistants who present the lab portion of the course. The UPII teaching assistants take a week-long TA preparation course with the rest of the departmental TAs. The teaching assistants that join UPII have little or no teaching experience and often serious deficiencies in their physics background due to ineffective undergraduate education at the university where they received their undergraduate degree. UPII must first make sure the TA understands the physics they are presenting, then make sure they understand how to correctly guide the students through the laboratory activities. The TA is asked to work the class homework and this is checked in the lab meeting. The first semester the TA attends the course lecture. The TA works the next week's lab and has them checked at the group meeting. Finally, his or her first semester the TA helps in an experienced instructor's (usually the lead instructor's) lab.