Physics Large Course Redesign Project Report

Course title(s): Physics for Engineering and Science
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1. Project Abstract/Description

Department of Physics and Optical Sciences has been active in online course design over the past 5 years, and has recently piloted a hybrid course delivery method for its calculus based Physics I (PHYS 2101) and is moving forward by implementing a hybrid course format for all its calculus-based physics courses (PHYS 2101 and 2102) as well as piloting a hybrid format for algebra-based PHYS 1101 in Fall 2011.

Space and financial resources are becoming increasingly limited as student enrollment is rapidly increasing. In order to meet this educational demand, we are actively pursuing new methods and tools for an effective college level physics education. We believe that creative use of virtual space will allow us to leverage technology with less actual physical space, thus resulting in a net reduction of cost without a commensurate reduction in the quality of the physics education that we offer.

The current project affects 4 of our introductory service physics courses, namely: PHYS 1101, 1102, 2101 and 2102. The enrolment for these courses has grown by more than 40% over the past 5 years and the enrollment trend is such that we would expect similar growth in the future. There are 10 sections all together per semester and the enrolment for each section is approximately 110. Each section involves two 75-minute lectures per week which are delivered by the faculty.

The redesign increases the enrolment per section to 160 students. The planned hybrid course format gives students the responsibility for first exposure to the material through online activities and assessments (i.e. reading posted pre-lecture reading material, viewing lecture videos and answering pre-quizzes) that are completed prior to class. Class time is then used to summarize content and deal with misconceptions, subtleties, connections and applications. The second 75-minute lecture time is now replaced with a problem solving session in groups of 30 to 40 students conducted by trained GTA’s. Thereby, a formal recitation class is added to the schedule which assists in students’ learning.

2. Representative Images of the Project

The main principles of the redesign involve the following:

1. Break down student learning process into multiple well defined, small and manageable steps, each with clear goals and deliverables with clear deadlines
2. Introduce the concept of pre-lecture study and switch to more interactive learning technique
3. Provide weekly feedback mechanism for students to monitor own progress in the course
4. Make course material available 24/7 (lecture notes, demonstration videos, practice problems, etc.)
5. Create small-group settings to encourage dialogue and discussion

The first task was to choose a suitable text for the redesigned course. The text has an online course material delivery system (Connect Plus of McGraw-Hill) which supports an interactive e-book. The interactive e-book feature enables the instructor to post notes within the text,
highlight sections of a chapter or assign reading material online, which are then available to all students when they access the e-book.

Schematic below shows the comparison of what students do weekly in a traditional course with that in the hybrid one:

**Traditional:**

Traditional:  
Lecture → Lecture → Quiz → HW

**Hybrid:**

Hybrid:  
Pre-lecture Reading → Pre-Lecture Quiz → Lecture → Practice Problems → Problem Solving → HW

Solid boxes represent 75-minute face-to-face instruction  
Dashed boxes represent online activity

Image below are screenshots of new course materials and student learning scenes:

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[Images of course materials and student learning scenes]

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**Physics 2101**

**Rotation**

**Instruction:**
1. Read your textbook Chapters 10, 11, 12, and 13.
2. Log into Connect Plus and answer the pre-lecture quiz.

**Kinetic Energy of Rotation:**

Rotational KE Calculator

Let’s consider a particle of mass m moving around a point O on a circular path with radius R. The particle has linear velocity v along the tangential path. The kinetic energy of the rotating particle is:

\[ K = \frac{1}{2} m v^2 \]

Let’s define a new physical quantity called the moment of inertia I:

\[ I = m R^2 \]

The SI units of moment of inertia is (kg m^2).
3. **Impact on Student Learning**

1. **Improved Learning**

   In the hybrid course, the quality of the educational experience is enhanced as the course moves from a faculty-centered, passive-student environment to a student-centered active learning environment. Students are engaged intellectually as they are introduced to a media-rich environment that includes collaborate learning activities and an inquiry-based curriculum. All homework is completed and graded online, giving the students immediate feedback on their assignments. Student progress is closely monitored, and both faculty and GTAs provide individual assistance to students who need help.

   In the proposed hybrid method, all course material is available to students at all times. Face-to-face in-class time is devoted more to problem solving strategies and worked examples rather than traditional lecturing. However, most importantly, students benefit from the added small-size recitation classes.

   Course material development is common for all sections, which means all students benefit from the same high quality of material. The evening sections of these courses are often times taught by part-time faculty. Having a common course material available to all students mitigates variations introduced by having part-time faculty involved.

2. **Improved Retention**

   The impact of the pilot redesigned course was assessed using the following criteria:
   - Final exam scores
   - DFW rates
   - Student evaluations
   - Midterm student surveys

   The table below shows the end of the semester performance results:

<table>
<thead>
<tr>
<th></th>
<th>Performance of 2 traditional sections</th>
<th>Performance of 1 hybrid section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spring 2010</td>
<td>Spring 2011</td>
</tr>
<tr>
<td>Number of Students</td>
<td>238</td>
<td>110</td>
</tr>
<tr>
<td>Coursework Scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homework</td>
<td>65%</td>
<td>73%</td>
</tr>
<tr>
<td>Quiz</td>
<td>56%</td>
<td>47%</td>
</tr>
<tr>
<td>Tests</td>
<td>69%</td>
<td>78%</td>
</tr>
<tr>
<td>Final Exam</td>
<td>60%</td>
<td>68%</td>
</tr>
<tr>
<td>Total Grade Point</td>
<td>65%</td>
<td>82%</td>
</tr>
</tbody>
</table>

   The only category where we did not observe an improvement in student performance is in the area of quizzes. We attribute this to the fact the students were allowed to take quizzes after lectures in the traditional course, whereas in the redesigned course, the quizzes are taken before attending the lecture.

   It should also be noted that there was a strong correlation between final course grades and what student surveys indicated as to what grade students themselves expected to get. Without wishing to psychoanalyze the situation, we believe that reinforcing students’ belief in
themselves through providing real-time performance feedbacks may have played an important role in their increased overall success.

3. Other Impacts on Students

Student perception on the new format was measured through mid-semester survey and end of semester student evaluations. The following graphs reflect the outcome of the mid-semester student surveys.

The above graph is summarizes students’ responses to questions regarding the following activities:

- Video lectures
- Online homework
- Pre-lecture quizzes
- Posted reading material
- Online practice problems
- Problem solving sessions
- Weekly tests
- In-class lectures
- Interactive e-book

The following course activities are useful/effective for my learning:
Students were also asked about the learning or practice on the following content:

- Basic principles of laws of physics
- Problem solving strategies and techniques
- Applications of physics in engineering

The course provides enough learning or practice on the following content:

Responses to select other questions are given below:

I am learning a lot in this course.

I am putting enough effort into this course.

What grade do you expect in this course?
### 4. Impact on Cost Savings

(How much you saved cost by redesigning, and kinds of cost saving strategies you used such as changes in the overall time spent by the instructors including faculty, GTAs, and undergraduate assistants, use of instructor time to improve student learning, use of classroom space, etc.)

The total cost of the redesigned course is estimated to be $92 per student compared to the cost of the traditional course which is $134 per student; i.e. cost savings of 31% per student.

Currently, the courses mentioned above serve approximately 2,570 students per academic year. The redesigned courses will serve up to 4,000 students; i.e. an increase of 45%. In addition, due to reassignment of some faculty duties to TA’s, there is a potential to add seven (7) new sections (to the existing 25 sections) while maintaining the same level of faculty and increasing number of TA’s only. This translates to an enrolment capacity of 5,200 students; which is a factor of two (2) increase over our current capacity.

Details of the cost analysis are tabulated below:

<table>
<thead>
<tr>
<th>Instructional Costs of FACULTY TAs/GAs</th>
<th>Redesigned Course # of Hours</th>
<th>Total Cost</th>
<th>Traditional Course # of Hours</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Course Preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Curriculum Development</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>B. Materials Acquisition</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>C. Materials Development</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>1. Lectures/presentations</td>
<td>7</td>
<td>$381</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>2. Learning materials/software</td>
<td>7</td>
<td>$381</td>
<td>5</td>
<td>$167</td>
</tr>
<tr>
<td>3. Diagnostic assessments</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>4. Assignments</td>
<td>12</td>
<td>$664</td>
<td>12</td>
<td>$400</td>
</tr>
<tr>
<td>5. Tests/evaluations</td>
<td>40</td>
<td>$2,179</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>66</td>
<td>$3,595</td>
<td>17</td>
<td>$867</td>
</tr>
<tr>
<td>D. Faculty/TA Devmt/Training</td>
<td>1. Orientation</td>
<td>4</td>
<td>$218</td>
<td>4</td>
</tr>
<tr>
<td>2. Staff meetings</td>
<td>15</td>
<td>$817</td>
<td>5</td>
<td>$167</td>
</tr>
<tr>
<td>3. Attend lectures</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>19</td>
<td>$1,035</td>
<td>9</td>
<td>$300</td>
</tr>
<tr>
<td>Total Preparation</td>
<td>85</td>
<td>$4,630</td>
<td>26</td>
<td>$867</td>
</tr>
<tr>
<td>II. Course Delivery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Instruction</td>
<td>1. Diagnose skill/knowledge</td>
<td>0</td>
<td>$0</td>
<td>0</td>
</tr>
<tr>
<td>2. Presentation</td>
<td>36</td>
<td>$1,061</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>3. Interaction</td>
<td>90</td>
<td>$4,503</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>4. Progress monitoring</td>
<td>0</td>
<td>$0</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>126</td>
<td>$5,664</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>B. Evaluation</td>
<td>1. Test proctoring</td>
<td>6</td>
<td>$327</td>
<td>6</td>
</tr>
<tr>
<td>2. Tests/evaluation</td>
<td>16</td>
<td>$672</td>
<td>16</td>
<td>$533</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>22</td>
<td>$1,198</td>
<td>22</td>
<td>$733</td>
</tr>
<tr>
<td>Total Delivery</td>
<td>148</td>
<td>$6,862</td>
<td>22</td>
<td>$733</td>
</tr>
<tr>
<td>TOTAL</td>
<td>257</td>
<td>$14,000</td>
<td>22</td>
<td>$733</td>
</tr>
<tr>
<td>GRAND TOTAL per Section</td>
<td>$14,751</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total # of students per Section</td>
<td>110</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per student</td>
<td>$134</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of sections</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Number of Students</td>
<td>625</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Cost</td>
<td>$368,774</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Lessons Learned

1. Pedagogical Improvement Techniques

The main issue we faced to implement new teaching methods was in relation to the somehow steep learning curve associated with the new online course material delivery platform adopted. It is important to appreciate technology related issues that students may be facing and show the right amount of flexibility, particularly early in the semester, and provide means of support to assist them in their learning process.

2. Cost Reduction Techniques

Small Room Requirement

In addition to the existing one large lecture hall (Burson 121) being used for all introductory physics courses, it is of utmost importance to have two (2) dedicated 40-seater rooms to hold the GTA run problem solving sessions. Once again, close dialog with the Undergraduate Program Coordinator and the Registrar’s Office is important.

GTA Support

Each GTA covers six (6) 75-minute long recitation classes per week. With current load of sections being considered for redesign, we require 4 GTA’s per semester. The GTA requirement is currently met with the existing GTA line in our department. Close coordination with the Graduate Program Coordinator and the Department Chair is key to ensure getting adequate TA support for the program.

3. Implementation Issues

It is important to communicate to students the new structure for the course and why all the extra web-based activities were being added. Equally important is giving a clear description of what was expected of them to do prior to coming to lectures and how to benefit from problem solving sessions. We used the diagram below to explain how the new structure helps in the learning process.

![The Learning Pyramid*](image)

*Adapted from National Training Laboratories, Bethel, Maine
It is equally important to communicate the redesign plan to faculty in the department. Departmental support is a key factor in assuring the success of the program. Foremost, the Department Chair must be kept appraised of the program on regular basis to ensure adequate and timely resource allocations. Other examples include:

1. Our Undergraduate Program Coordinator made all arrangements with the registrar’s Office to secure room space for break-out sessions as well as restructure the course registration format to accommodate the redesign criteria. Each section was turned into two separate sections, one with a lecture meeting on Mondays (or Tuesdays) and the other with lecture meetings on Wednesdays (or Thursdays). In doing so we were able to up the enrolment cap per section by 15% from last semester to present. We have room to up the enrolment cap by 100% if necessary without the need for a bigger lecture hall.

2. Our Graduate Program Coordinator was instrumental in making sure the program received the quality needed GTA support. Physics GTA’s run labs, do grading, and now that the redesign project is underway, conduct problem solving sessions. Prioritizing GTA assignments is important for the success of the project.

3. Soliciting the assistance and inputs from Directors of Center for Academic Excellence as well as Department of Engineering’s MAPS Program gave us a better insight to engineering students’ success in physics courses and led to Supplementary Instructional (SI) sessions being offered to both PHYS 2101 and 2102 courses in Fall 2012. Historically, SI sessions for these courses have been sporadic at best.

4. Regular meetings with members of the Center for Teaching and Learning can not be emphasized enough. The guidance and hand-holding and the CTL team offers is invaluable to the program.

5. Finally, exchanging experiences and lessons learned with other departments involved in similar programs can be useful in expediting the implementation process.

- Activities/Strategies that worked best

In our redesign, we broke up the learning activities into a number of small steps, each with well-defined deliverables and deadlines. Students were told that all this, while amounting to added work for both faculty and the student, was to assist them in their learning process. We believe that the achieved increase in the Final Exam scores in the pilot section versus those of previous semesters bears witness to increased student learning in the new format.

In our department, we have a dedicated Physics Resource Center, staffed by TA’s Monday-Thursday from 9 AM – 5 PM and one evening a week from 5 PM till 8 PM. There are 24 computers with internet access and ample desk space for students to complete their assignments. We encourage our students to form study groups and work collectively.

Replacing the two midterm exams given in the traditional method with 13 single question mini tests administered every week in the problem solving sessions not only addressed the “big exam” anxiety factor among some students, but also provided a mechanism for weekly progress feedback for all students. Right from the beginning of the semester students were able to monitor own progress in the course and adjust study habits accordingly.
Eliminating midterm exams, which were common exams, also eased the requirement for large lecture halls campus wide. The Final is also a common exam, and its format has not been changed relative to the old format.

- Activities/Strategies that worked least well

There is still room for improvement in the area of video lectures. It is important to make the videos palatable by making them as much modular, concise and easy to download and view as possible.

6. **Sustainability**

We have demonstrated feasibility of the redesigned course format in our pilot program, with positive impact on both pedagogy and instructional cost.

**Additional TA-lines**

Sustained implementation will require allocation of additional TA lines. Success of the program depends on high-quality TAs with native-level fluency in English. We will need to make nationally-competitive offers to recruit domestic graduate students. Typical TA load will be 5 student-contact hours per week.

**Additional small classroom**

Sustainable implementation of the redesigned courses also requires one additional dedicated 40-seater classroom to hold problem solving sessions. There is currently only one dedicated room in Burson and make do with a number of different rooms scattered around campus to hold the parallel problem solving session for each section of the course. Having a second dedicated room would ease scheduling of classes and lessen confusion for our students.

Implementation timeline to sustain/expand the new course format is shown below:

<table>
<thead>
<tr>
<th>Plan/Develop</th>
<th>Pilot</th>
<th>Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 2101</td>
<td>Fall 2010</td>
<td>Spring 2011</td>
</tr>
<tr>
<td>PHYS 2102</td>
<td>Spring 2011</td>
<td>-</td>
</tr>
<tr>
<td>PHYS 1101</td>
<td>Spring 2011</td>
<td>Fall 2011</td>
</tr>
<tr>
<td>PHYS 1102</td>
<td>Fall 2011</td>
<td>-</td>
</tr>
</tbody>
</table>

The activities we are doing currently involved in to achieve sustainability include:

**Course specific video demonstrations**

We have developed high definition demonstration videos of 3 to 4 minutes length by utilizing already available lecture demonstration equipment to enhance the understanding of physical concepts of the introductory physics course students. The project will be available first to the mechanics courses (PHYS 2101 and 1101) through the internet, iPod, iPad and iTunes platforms starting in Fall 2011 semester, then it will be generalized for the electricity and magnetism (PHYS 2102 and 1102) courses starting on Spring 2012 semester.