CELT Summer Course Development Report

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A few years ago, after collaboration with Ann Marie LeBlanc from Visual Arts and David Maloney of Physics on a Catholic School's teacher in-service, I realized that I could teach physics through the medium of computer graphics. At the time I had just started to work with computer graphics as a hobby. Given the concurrence of my hobby and the possibility of teaching physics, I rapidly developed Physics 127: Physics for Computer Graphics and Animation. I had intended this course to cover both issues of light and motion through computer graphics. However, when I first taught the class, I found that I had too much material for the course to be satisfying in terms of student learning. The course was broken into two sections. The first semester concentrated on light and color, while the second semester would contrite on motion. The second course became Physics 326: Physics for Computer Graphics and Animation II. This course was up for initial enrolment for the Fall 2005 semester at which point I realized that it was going to be a daunting task to teach this course.

In Physics 326 the students are supposed to learn the basics of motion and apply these basic motion concepts to the motion of living creatures of various forms: living, prehistoric, imaginary. The materials that need to be covered in this course are basic Newtonian physics, biomechanics and scaling. The ultimate goal of the course was for the students to apply the material from class to creating a creature and accurately animating its range of motions.

To help prepare for this new course I applied for and received a CELT Summer Course Development Grant. In the proposal I described the development of four types of materials necessary to assist with the pedagogical approach I intended to use (interactive engagement).

These four materials consist of 1) short tutorials on the basic physics as a class manual, 2) "worksheets" to help develop and guide the discussions, 3) homework assignments for the class, and 4) assembly of appropriate "laboratory" experiences for the students.

As often happens when one starts working on a project that has been planned for a long time I found myself at a less concrete stage than I thought. There were numerous issues that I had to be concerned with such as what is the logical conceptual flow of the course material. What must be excluded to make sense of the later material? In particular, if I were to look at the physics of motion, there is linear motion and rotational motion. Is it necessary to cover the rotational motion aspects? These were difficult questions for me without previous experience with this class.

Furthermore, I am a laser physicist and biomechanics is not my speciality. As such I had to research biomechanics, finding appropriate materials and interpreting them in a satisfactory way. Much of the available material on biomechanics is not written in a way that is satisfying to a physicist so that I spent a large amount of time trying to relate what I learned back to the physics of motion and then trying to determine how to conceptually present this material. There were two aspects of biomechanics on which I wanted to focus: the biomechanics of motion and scaling. Biomechanics of motion goes beyond describing motion and considers the biological mechanisms behind the motion. This can be exceedingly difficult since we have to describe biological structures and their basic function. If this is appropriately developed then it segues directly into scaling. This means that everything is developed in terms of dimensionless quantities such as the ratio of the change in length to length. Scaling allows us to determine what happens with change in size of a creature. The idea of scaling has been around since Galileo when he used scaling to show why there are no giants. There are numerous interesting questions such as: can elephants jump (no), can mice juggle (no), why can a mouse survive a fall from a great height while a dog, or a rat for that matter, cannot.

The initial part of the class was to be based on Newtonian Mechanics. Previous experience with introductory physics has taught me that there are many serious conceptual hazards that need to be addressed. For creating appropriate materials on these issues I borrowed heavily from material produced for my introductory physics courses. However, there were still difficult issues with how to incorporate the animation with the mechanics. My initial thoughts had been to have the students animate objects such as balls. However, after several meetings with and suggestions by Samantha Birk and Gail Rathbun from CELT, I was convinced that a logical starting point for animation was the activity of jumping. In particular the students would concentrate on a bipedal creature simply jumping up and down, a standing jump, walking with various speeds and running. I created a series of laboratory activities which investigated jumping. In the first activity, the students created a jump as they thought best. The next two activities required (led) the students to think through the physics prior to creating the jump animation. A later sequence of activities that I developed made the students work through the motion of a walker walking slowly increasing their speed. Two Final projects that proved very difficult for the students were creating a walk cycle for a quadruped which required external observation and research, and also the issue of a transition from walking to running.

Besides creating the “laboratory” activities discussed above I also produced a number of handouts that described which basically summarized the material we worked with and also worksheets that help lead the students to work through the material. These handouts were: Describing Motion; Forces, Statics and Motion; Rotational Equilibrium and Motion. Unfortunately, there were several tutorials that I did not complete. These incomplete tutorials were in the section of biomechanics and scaling in part because I was uncertain where the students would have conceptual difficulties with the material. I also had difficulty creating worksheets on biomechanical issues since I was uncertain how that part of the course would go. Having had this experience with the course, I have some better insight on how to proceed with the biomechanics and scaling and feel rather excited.

The main task in need of completion is the creation of more handouts and worksheets about basic biomechanics, applications of biomechanics, scaling and flight. These will be easier to produce since I have some experience with teaching the material. I will continue with writing this material during the upcoming semester and summer prior to offering the course again (Fall 06). As mentioned above, I also need to rework both the in class assignments and the home assignments. I need to determine what can be logically trimmed from the course subject such as rotational motion. Finally, based on comments by the students of this past semester I need to provide them with a series of models with which they can work.

The primary evaluation plan was based on a standard conceptual physics examination (Force Concept Inventory). The students took the test at the beginning of class and then again at the end. While I had very limited class size (five students) the measures of student learning based upon comparison of pre-test scores and post-test scores were perhaps the worst I have ever had on an individual level. One of the five students had an incredible improvement in his scores, two were about average and two showed no improvement (of course, if I look at the class average improvement, they improved more than the national average!). I found this both disheartening and frustrating.

On the other hand, with a different measure that I developed for this project the students were presented with an animation showing some motion. The students were required to articulate what, if anything, was wrong with the motion. At the beginning of the semester the students might respond that either there was nothing wrong with a particular motion (even if there were serious defects) or say there was something wrong but be unable to identify exactly what was wrong. By the end of the class they were all able to identify and describe problems and explain why this was a problem. So that was more satisfying.

Towards the end of the semester I had a feeling of general disappointment in the way the class went with both the material we covered and the overall learning of the students. This is often the case for many of my classes since there is a feeling of lost opportunities. In Physics 326, I was disappointed that I was unable to cover as much of biomechanics as I wanted. I also found that the introductory physics materials needs to be further modified to more closely relate to the core material of the course. In many ways it was too mechanistic an approach for my audience. I was satisfied with the laboratories that I developed but found that they took much longer than I had expected.

I also encountered a number of problems with this class, some of which surprised me. First, for a very small class, attendance and tardiness became an issue. For some reason several of the students had the belief that they need not attend regularly or appear on time for class often being an hour late for a two hour class. This may have been because both of these students had health problems or perhaps it is a cultural issue (the students were all members from VPA). However, even though these students did not regularly attend, they did not endeavour to catch up with the other students in class and would often be a drag on the class. The small class also had a surprising impact on the discussions. I found that the students were much more reticent to talk about the material than these same students had been in larger classes with me. I am still considering the issue of small class interaction. I have worked with small classes before, but this one was particularly reticent.

A second issue was that the student's mathematical skills were not as good as I had hoped. One reason that this class is a 300-level GenEd Area VI class was so that I could make certain that the students had some grounding in mathematics. This was not an accurate expectation and required that I spend some class time on mathematical reasoning.

A third issue that I encountered was that the activities that I designed such as the creation of the jump took much longer for the students to execute than I had anticipated. I had thought that each step of the three jump projects would require two hours. It turned out that the second two jumps required about four hours each to complete. This time was spent predominantly in working through the physics. While I believe that these were useful and successful tasks, the expansion of the time required to complete the projects meant that there was less time to complete other projects. Finally, I found that I again had my usual lament that I wanted to cover too much material with too little time available.

A fourth issue of which I am uncertain how to address is my ambivalence to technology in the classroom. If a technology is transparent to the student then there is no problem with using that technology. However, in situations such as that of this class in which the technology (computer animation software) is an important tool for the course, there is the issue that the technology becomes the focus of the course to the students. I am still struggling with a method to address this issue. One thought, which I have used in our computer based introductory physics laboratories, is to use the technology very specifically and repetitively so that it becomes routine thus removing the technology roadblock. To do this in my animation classes I have to provide the students with pre-made models so that they do not have to be concerned with the creative aspects, only the motion aspects. If the students do this enough, they will be less concerned with the specific details of creating an animation than with the motion. However, since the end goal of the course requires some creativity, how can that be incorporated into this approach? This requires more thought.

Overall, I believe this project was a success. The more I worked on this project, the more convinced I have become as to its value. There are a large number of interesting aspects of physical motion to be explored. For example, simply considering how one walks and runs is fascinating and is a question that physicists often ignore. What goes on when we transition from walking to running, or for that matter what is running, is remarkable. Why should we run? These are questions which I was answering that I had never really thought about previously. This type of material also transfers to other classes such as Introductory and Intermediate Mechanics and can make those courses more interesting. Another interesting question which I plan to investigate is how much of the physics of motion can be taught through the medium of computer graphics as opposed to traditional approaches as well as the issue of being able to articulate observed physical problems.