ENHANCING THE TEACHING OF CONTEMPORARY PHYSICS THROUGH ONLINE INSTRUCTION FOR TEACHERS

N. Sanjay Rebello, Dean A. Zollman, Kirsten Hogg & Salomon F. Itza-Ortiz
Kansas State University, USA

ABSTRACT

There is a critical need for high quality science (physics, physical science) teachers in the United States. We have developed an online course to help in-service teachers update their pedagogical and content knowledge about contemporary physics. *Contemporary Physics Online* adapts an existing on-campus course for Internet delivery. The course utilizes computer programs and hands-on activities to focus on 20th Century physics. Experiment kits are mailed to the teachers. These teachers also participate in a summer workshop after completion of the online component. We provide follow-up support to facilitate the development and transfer of new teaching materials into their classrooms.

THE PROBLEM

In the U.S. high school physics and/or physical science teachers are not being produced at a rate that is sufficiently high to meet demand. Further, a fully trained high school physics teacher is also a well-educated scientist who can easily find a position different from teaching. As a result, a very large fraction of the high school physics teachers in the U.S. are teachers of other sciences, mathematics and other subjects who have been pressed into service in the physics classroom. These teachers are well intentioned and do the best that they can, given their limited background in both content and pedagogy of physics. However, they frequently need additional support to improve their abilities.

Many of these teachers need to bring their content knowledge about physics up-to-date. This content knowledge includes topics such as 20th Century physics and its application to modern technology. These topics are at best glossed over in traditional curricula for teacher preparation in the U.S. However, these contemporary physics topics could serve as a useful tool to motivate the students of tomorrow who will encounter these devices in their everyday lives.

In addition to the content knowledge about 20th Century physics, many of these teachers who were not trained to teach physics at the secondary level, may need to update their pedagogical content knowledge so that they can expand their range of technological and pedagogical skills to teach contemporary physics.

Typically, the updating of the content and pedagogical knowledge is accomplished through in-service workshops or university courses. For many teachers workshops or courses held at distant universities are not acceptable options. Ones conducted in the local schools, particularly for physical science teachers, have too few participants to be cost effective. Thus, we need to look at other options for enhancing the skills of in-service teachers.

A SOLUTION

The rapid expansion of information and computer technology (ICT) provides a solution to the above problem. Without question this expansion has, and will continue to have, a large influence on all types of teaching and learning at universities (McCormack & Jones 1998). It can have an immediate impact on the education of in-service teachers. University faculty and other instructors can offer education for teachers via the World Wide Web. This education can be delivered anywhere and gives in-service teachers the opportunity to enhance their knowledge of subject matter and pedagogy without physically moving to a campus. This advantage is particularly relevant to teachers in remote areas of predominantly rural states in the U.S. such as Kansas, who often do not get opportunities to interact with their counterparts at other schools.

THE PROGRAM

To address the needs described above we designed an educational program that includes a Web-based course that in-service teachers complete for college credit and a support structure to help implement new teaching materials for physics and/or physical science in their classrooms. The project was funded by a U.S. Department of Education Eisenhower Program. The goals for our course are to:

- provide an opportunity for under-prepared physics and/or physical science teachers to increase their knowledge, proficiency and confidence in the physics content,
- present the material using pedagogy suitable for effective student learning, fast transfer and easy reproduction in the teacher's own classroom,
- provide a community and support structure so under-prepared teachers feel less isolated than they do now, and
- increase the number of teachers certified to teach physics and/or physical science.

To achieve these goals we implemented a new course, *Contemporary Physics Online*. This course combined an existing successful on-campus course with computer and Internet technologies thus enabling teachers to complete the course without having to travel to a college campus. In addition we provided a summer workshop and follow-up support to facilitate the development and transfer of new teaching materials by these teachers into their classrooms. This project was a collaborative process between university faculty, high school and middle school teachers as well as pre-service secondary education students at Kansas State University.

THE CHALLENGES

Adapting a successful on-campus course to an online environment involves several challenges. First, the on-campus course functioned in a constructivist format based on collaborative learning and student interaction. It is important to preserve these elements in the online course.

Second, the on-campus course was based on hands-on and computer activities. While the computer activities were relatively easy to transfer to an online environment, it is important to provide the required equipment opportunities for the students to do the hands-on activities at home.

Finally, it is important to provide useful and timely feedback to the students in the online course. While feedback is an important component of any course, it is especially so when the students and faculty do not have opportunities to meet face to face.

THE ONLINE COURSE

For nearly two decades Kansas State University has offered a course, *Contemporary Physics,* specifically tailored to secondary education majors preparing to teach physics in Kansas middle and high schools. The course is strongly activity-based and students work through a series of explorations and applications to build an understanding of energy conservation, particle and wave nature of electrons, wave functions and other quantum physics concepts. The course has evolved to incorporate the latest in computer technology, interesting and modern hands-on activities and sound science pedagogy.

To make this course more accessible to under-prepared physics teachers in Kansas we adapted this course to an online format. We have made every effort to preserve the successful teaching and learning environment of the existing course by including computer-based and hands-on activities, message boards and a virtual classroom.

The online course is organized into modules, each containing several topics. Students work at their own pace through the modules. The hands-on activity kits are shipped to each student so that they can perform the activities in much the same way as they would in an on-campus course. Most of the items in these kits are low cost and can be reused (See Fig. 1). The course materials include suggestions and instructions for using these materials in the classroom. Additionally, the students also purchase a set of reading materials pertinent to the course.

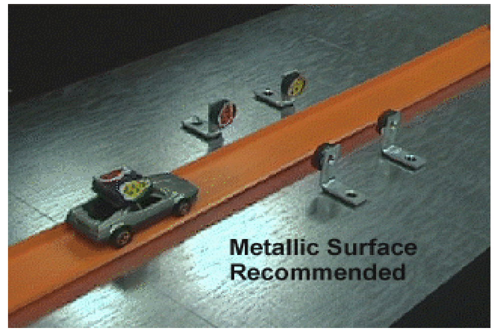
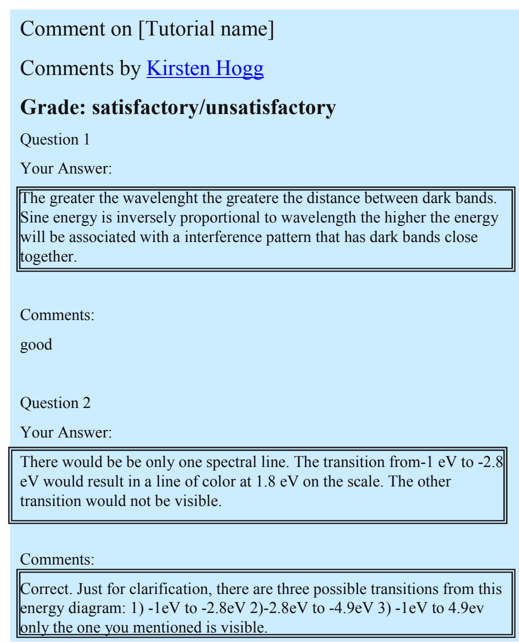


Fig. 1: Example of the inexpensive equipment used in the potential energy diagrams module.

Much like the on-campus course the students are required to submit numerical and written answers to questions throughout the module. Unlike the on-campus course, however, where these exercises are completed on paper, here students type their answers into a form on the Web page for the course materials. The students' answers are stored in a database and are promptly reviewed by the instructor. The format allows the instructor to provide detailed individualized feedback for each question. (See Fig. 2)


Comment on [Tutorial name]

Comments by Kirsten Hogg

Grade: satisfactory/unsatisfactory

Question 1

Your Answer:

The greater the wavelenght the greatere the distance between dark bands. Sine energy is inversely proportional to wavelength the higher the energy will be associated with a interference pattern that has dark bands close together.

Comments:

good

Question 2

Your Answer:

There would be be only one spectral line. The transition from-1 eV to -2.8 eV would result in a line of color at 1.8 eV on the scale. The other transition would not be visible.

Comments:

Correct. Just for clarification, there are three possible transitions from this energy diagram: 1) -1eV to -2.8eV 2)-2.8eV to -4.9eV 3) -1eV to 4.9ev only the one you mentioned is visible.

Fig. 2: Example of the individualized feedback as seen by the student.

In the online modules, students also use computer-based activities to supplement and, where necessary, replace the hands-on activities. A large variety of interactive simulations that had been developed for the Visual Quantum Mechanics (Zollman & Rebello, 2002) project are used. The students do not need to purchase any special software to run these programs. The programs (See Fig. 3) can be run online by downloading (at no cost) the Macromedia Flash plug-in. We also supplement the hands-on activities using QuickTime videos of real experiments.

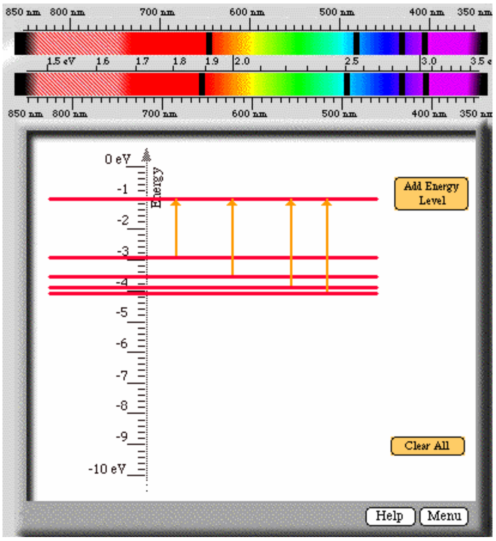


Fig. 3: An interactive computer program to study light absorption by gases.

When a module is completed the student answers a set of online questions to assess her/his understanding. There are three tests and a final exam, all of which are administered online.

COURSE CONTENT & PEDAGOGY

An outline of the online course is presented in Table 1. The course uses the Learning Cycle (Karplus, 1977) as a pedagogical model. A significant body of research (Lawson, 1995 and Karplus & Karplus, 1970) has shown this pedagogical strategy to be effective with students ranging from elementary schools to the advanced college level.

Contemporary Physics Topic Outline
1. Energy, momentum and charge of a system of particles
2. Light emission from gases and solids
3. Building an energy model of atoms
4. Energy models for solids
5. Wave behavior
6. Particles behaving like waves
7. Potential energy
8. Wave functions and Schrödinger's Equation
9. Barriers, wells and tunneling
10. Uncertainty principle
11. Three-dimensional atoms
12. Radioactivity

Table 1: Outline for Contemporary Physics Online.

Students begin with an exploration activity that involves a hands-on experiment or computer visualization. We make use of interactive video and the computer programs developed for the Visual Quantum Mechanics (Zollman & Rebello, 2002) project where the real experiment is unavailable for online students. Following the exploration activity, the new physics concept is introduced and application activities further understanding of the concept.

In the initial stages of the project we asked several participating teachers to interact with the new online course. Then in the following semester (spring 2001), these secondary science teachers formally enrolled in *Contemporary Physics Online* for college credit. Other more experienced physics teachers were also asked to review the course informally and provide feedback. In addition, pre-service teachers enrolled in the on-campus *Contemporary Physics* course taught at Kansas State University during the spring 2001 semester were invited to participate in the project. These students were encouraged to access the online resources to supplement their on-site instruction.

THE SUMMER WORKSHOP

The second stage of the project involved an intensive summer workshop for all of the collaborators (university faculty, participating in-service teachers and pre-service teachers). The workshop focused on five major issues:

- <u>Physics content</u> – An in-depth look at selected physics content covered by the online course was offered with opportunities to use additional hands-on activities and laboratory experiments.
- <u>Pedagogical strategies</u> – We reviewed and discussed the pedagogy used in the online course. Sessions on the Learning Cycle, activity-based learning and how to promote better teaching and learning in the classroom were included.
- <u>Technology issues</u> – A review and discussion of technology used in the online course was conducted. Demonstrations of various technologies (computers, multimedia, etc.) and how to use them in the classroom were shown.
- <u>Changes and improvements made to course</u> – Based on participants' experiences with the online course, we formed teams to review, evaluate and improve selected portions of the online course.
- <u>Transfer of materials to the classroom</u> – Participants worked in teams to refine and/or restructure selected materials for use in secondary classrooms.

The feedback obtained from interaction with the online course was used as a major resource for the workshop.

PREPARATION OF NEW TEACHING MATERIALS

One of the most important aspects of this project is facilitating the transfer of materials from this project to the classrooms of participating teachers. We encourage the participants to continue using the Learning Cycle in their classes by using it during the course and in the preparation of teaching materials.

The third stage of the project was designed to help the teachers transfer their physics knowledge and pedagogy developed in the online course and workshop to Kansas' classrooms. The basic lesson plans for topics in *Contemporary Physics* exist in the material that our group has produced. However, each classroom is unique, so modifications of the existing materials or pedagogical strategies were needed. Our previous experience had indicated that teachers working together provide an excellent way to create lesson plans from the newly introduced scientific concepts. The teachers in the program will have different experiences in the classroom and, thus, will bring different ideas to the lesson planning activities.

We built teams consisting of in-service teachers, college faculty and pre-service teachers to assist with development and implementation of the teaching materials. In the project's second year (2002) we gave teachers the opportunity to exchange experiences of using the new materials in their classrooms. We also found that this gives other teachers ideas to use and helps them refine their lessons. With help from the project staff, these teachers were able to build lessons that fit their unique situations and students.

OUR IMPRESSIONS

Until this past year, about a dozen in-service teachers had completed the online course. About half of these have also participated in the summer workshop. No formal evaluation of the project was conducted. However, through our interactions with the in-service teachers and observing their use of the materials, we developed several impressions that would be useful to the development of future online courses for in-service teachers.

We noticed that the online mode of learning favors highly motivated and independent learners. Since there are no formal class meetings or firm deadlines, some of the students who were not highly motivated tended to fall behind. In future implementations we plan to enforce the course timeline more strictly.

We also found that students with recent prior experience in physics tended to have an advantage in this course. They seemed to ask more questions and interact with the computer programs and other materials more actively than students who did not have recent prior experience. While this issue would be true for an on-campus course as well, we believe that it is exacerbated by the online nature of the course.

Another problem with the online course is the lack of group interaction. These experiences could conceivably be set up using a virtual chat room. However, the true dynamic of a face-to-face group interaction cannot be completely replicated online. Therefore, students in the online course did not have as much of an opportunity to interact with their peers.

Finally, a few of the students also complained that they found it uncomfortable to read off the computer screen and answer the online questions in the activities. We believe that this and similar issues pertaining to screen layout can be addressed rather easily in future versions of the course.

From the instructor's perspective, the online individualized feedback required a considerable amount of time and effort. The instructor also felt that requiring the students to contribute to an online threaded discussion mediated by the instructor via the message board would have enhanced the interaction between students so that they could share ideas and help each other address problems that they encountered.

Overall, the impressions of both the students and the instructors were highly positive. Notwithstanding the issues discussed above, the online course provided an excellent opportunity for teachers to update their content and pedagogical knowledge. It also gave them an opportunity to share ideas about teaching contemporary physics topics with other teachers in similar situations. We look forward to continuing this course in the future.

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