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Online Physics Homework and Resources in High Schools: A Case Study

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Abstract

This paper presents a case study of high school teachers' experiences using network technology in their classes. High school teachers confront a number of issues when implementing technology in the classroom. This paper describes a collaborative effort by high school science teachers to develop and identify appropriate materials for use with the LON-CAPA system. Examples of the materials they have created and used are presented. Teachers report high levels of satisfaction with the impact the technology has had on their teaching, both from their own and their students' perspectives.

Introduction

“The K-12 education system has changed considerably the last 5 years. The amount of time we have to do stuff is very limited right now. The State uses it up quickly with all of its paperwork and its testing and everything else ...”

A high school teacher in Michigan

High school physics teachers face numerous challenges today. Because the material they teach requires students to practice problem solving in order to learn the material, they must assign, and ultimately grade, lengthy homework assignments and exams. They are also often asked to teach courses from several disciplines (e.g., chemistry or biology), in addition to their core physics classes. The time pressures faced by high school teachers make them an important potential consumer of internet-based learning and assessment systems. Indeed most schools have made significant investments in computer technology. Yet, there seems to be room to improve how technology is integrated into the high school curriculum.

In this paper we describe our experiences and interviews with a group of local high school teachers as they have implemented the *LearningOnline Network with Computer Assisted Personalized Approach* (LON-CAPA) system [1]. We conducted detailed one-on-one interviews with six teachers and had discussions with eight other high school teachers who are using the system. These teachers have developed a set of online teaching materials, mostly homework or examination problems, specifically geared for

high-school courses. These resources are stored within LON-CAPA, and are available for use by all K-12 teachers using the LON-CAPA system.

A brief historical perspective on the CAPA and LON-CAPA systems

In the fall of 1992, CAPA (Computer-Assisted Personalized Approach) [2,3] was piloted in a small physics class at Michigan State University (MSU). CAPA provides students with personalized problem sets, quizzes, and exams. CAPA was initially used via Telnet, but switched over to the Web when it became widely available. In brief, with CAPA every student is given a different randomized version of each problem on a homework, quiz, or exam set. Students enter their answers via the internet and are given instant feedback and hints, and may correct errors without penalty until the assignment due date (the number of “tries” allowed is set by the instructor). The system records the students' participation and performance, and the records are available online to both the instructor and the individual student. A description of CAPA together with references to various studies on how it has been used to impact student performance is summarized in Ref [4].

In the spring of 2001 the LON-CAPA system was launched. This system integrates CAPA into a full-featured course and learning content management system (CMS/LCMS), which handles all aspects of running a course from the initial preparation and assembly of learning content to enrollment, communication, and grading. The system is both open-source and free of licensing fees.

The development of LON-CAPA represents a step up in both ease of use and functionality. The most important new functionality in the system is the ability to share educational resources within and across institutions simply and efficiently. It is this functionality that differentiates LON-CAPA from the vast array of other instructional technology systems available. Indeed, the way resources are created and shared within LON-CAPA is a realization of the initial reason for inventing the World Wide Web, and represents an achievement of the goal of collaborative editing along with viewing of documents [5]. A complete overview of LON-CAPA, together with relevant research publications and presentations can be found at <http://lon-capa.org/>

Currently, LON-CAPA serves well over 23,000 course enrollments system-wide at any given point in time. The vast majority of these are in university settings, but about 300 are in middle schools, and 500 are in high schools settings. Disciplines currently include astronomy, biology, business, chemistry, civil engineering, computer science, family and child ecology, geology, human food and nutrition, human medicine, mathematics, medical technology, physics, and psychology.

LON-CAPA in high schools

The high school teachers who have adopted LON-CAPA in Michigan have been introduced to the system in a variety of ways. Some teachers were students at MSU and took courses that used CAPA. Others became familiar with the system when they participated in the PAN (Physics of Atomic Nuclei) program, a summer program for

teachers held at MSU. Most recently, a number of teachers have been introduced to the system via the Research Experience for Teachers program sponsored by the National Science Foundation [6]. Although a number of disciplines are represented among the high school teachers now using the system, the majority of the teachers are in the natural sciences, including physics, biology, and chemistry.

The costs of starting out – Setting up the system

The teachers who adopted LON-CAPA, or CAPA in earlier years, encountered a variety of difficulties as they were starting up [6]. For example, LON-CAPA is generally run from a dedicated server at each institution. This represents a fairly significant start-up cost, and not all schools have funds available for such a purchase. One high school was able to acquire the necessary funds via an educational partnership grant with the Coca-Cola Company. Currently, different models for hosting are being investigated, in particular with respect to FERPA laws.

Early adopters (i.e., 1995-1997) also ran into hardware difficulties on the student side because many students did not have computers or internet access at home. However, the teachers we interviewed in 2003 and 2004 generally did not report problems with student access. The teachers estimated that over 80 percent of their students had internet access from home. All of these teachers also reported that students had access at school and at their local libraries. As one teacher said:

“It’s rare to have a student in class that doesn’t have access to it at home but it always happens. I’ve got a couple kids that don’t have home access to the internet, so we’ve got a couple of computer labs here at the school. They can come in before school and use my computer, they go to a friend’s house.... accessibility hasn’t been an issue that has caused kids any difficulty.”

The costs of starting out – problem/content location and generation

Without doubt, the biggest start-up difficulty has been the generation of appropriate problems and materials at the high-school level. LON-CAPA is a platform, not a curriculum, and so the actual materials must be still be developed or assembled. As one teacher (who was the only teacher in our group lucky enough to get a teaching load reduction so that he could create problems for LON-CAPA) stated:

“...it’s a huge time commitment and investment to generate problems.”

There are large libraries of college-level physics, biology, and chemistry materials (both homework problems and other educational resources) that university faculty have developed and have made available to all LON-CAPA users. One challenge high school teachers have confronted is how to find appropriate problems and materials from these large libraries of university-level resources.

A keyword based search engine is included in the LON-CAPA system to assist instructors in finding existing resources. With the search engine, acquiring an educational resource such as a physics problem concerning angular momentum, or a 1-

page procedure for the safe use and handling of a pipette is an easy operation. Keywords are provided by the author of the problem and are also proposed by the system at the time a resource is made available. Searches can be conducted within a specific library or across the entire LON-CAPA network (including libraries from the other universities and K-12 schools in the network). Additional cataloging information regarding appropriate grade levels and educational standards has been added in the most recent release of LON-CAPA. We note here that most teachers and professors have made their LON-CAPA resources freely available to colleagues for student use. However, it is possible to limit the distribution of problems across the LON-CAPA user network – as one would need to do if they were using copyrighted problems from the back of a textbook.

The greatest current use of the system at the high school level is for problem solving on homework. Some of the teachers we interviewed reported that prior to implementing LON-CAPA, they spent hours each day grading homework assignments. Other teachers reported that they did not grade homework – instead they simply gave students credit for completing assignments. For example:

“That’s one thing about teaching, you are always, always, always grading ... you’re just always carrying something home.”

Or:

“A typical physics week I’ll have 3-4 homework assignments from each student, there might be anywhere from 3-20 problems I have to do. I’ll give them a test and it sometimes takes me 2-3 days to get the tests all graded. No TA’s, it’s just me and that stack of 105 tests”

On the other hand:

“Did I grade the homework? Not really. I gave them credit for doing it and we would mostly check it together in class.”

Examples of high-school level problems in LON-CAPA

To give readers a sense of the types of questions high school teachers have written and are using on LON-CAPA, we have included several examples. Most of the physics problems written by the teachers are algorithmic, with numerical values differing among the students.

An entertaining example dealing with torque and equilibrium is shown in Figure 1, with all four numerical values changing from student to student [8]. Numbers such as the weight of the beam and the distance from the ends of the log vary from student to student – this is what we mean by “personalization.” Students must enter both the correct numerical value as well as the unit for that quantity to get credit. Students are encouraged to collaborate but cannot just copy because answers also vary from student to student.

A second example is a teacher who used the system to verify his students' laboratory calculations [9]. An experiment on friction is a good illustration. In the lab, students slowly increase the angle of a wooden board upon which there is a block at rest. They measure the angle at which the block begins to slide, and also the time it takes the block to travel a distance L . They enter their measured values into LON-CAPA. Students are then presented with a series of questions to which they respond as they would for any numerical problem, for example:

- Calculate the coefficient of static friction between the board and block.
- Calculate the acceleration of the block.
- Calculate the coefficient of dynamic friction between the board and block.

This represents a great saving in the teacher's time as students who do not carry out the calculations properly are so informed and can correct their work.

Although obtaining numerical solutions to algorithmic problems is a major task for science students, many of the teachers want to have students write and explain their work, in addition to getting a correct answer. The next example (presented in Figures 2 and 3) is a good illustration of how a yes/no problem can be transformed into an essay. Each student sees only the upper part of the figure, whereas the bottom parts are only visible to the instructor when they grade the online essays. The graphs in the two figures differ, as do the numerical values, and for fun, the names used. This problem requires students to write an essay in which they describe their conclusion and how that conclusion was reached. Each student types in his or her essay directly in a window provided, or, if allowed by the teacher, submits an electronic file.

Students must read the initial and final elevations of the ramp from their own graph. The initial speed is selected so that for about half of the students the skateboarder makes it to the top.

The system presents the grader with the information in the lower sections of figures 2 and 3 so that the grader can thus judge the quality of the student's calculations and explanations. For pure text submissions, the system performs an automatic plagiarism check against a database of all previously submitted essays. The grading tool also provides a convenient way to send feedback to the student. For this particular exercise, a student could agree with Carol (Figure 2) who is unsure of the outcome, but not with Terry (Figure 3), by arguing that the excess kinetic energy is very small. With good calculations, this would be reasonable 'out-of-the-box' thinking.

Putting the problems together - TheDump

The task of assembling a balanced homework set on a given topic can be substantial. Including appropriate educational resources to guide students can add significantly to the work. Such sets are now readily obtainable for topics in several science disciplines due to the work of members of an association of teachers that organized this past summer in Michigan. Aptly named TheDump, (Teachers Helping Each-other Develop Usable Materials and Problems), it is readily accessible to teachers.[12] The site is a repository, not of the educational materials, problems or exercises, but of the paths to such resources, grouped in work units or homework sets. The resources are organized by disciplines, and

by topics within the disciplines. In just a few ‘clicks’ a teacher can make any content referenced in such a group immediately available to students in a class. This is a much smaller task than assembling such a set from the multitude of individual resources scattered across the network.

“... now I see how easy it is to peruse libraries and look at stuff that’s already out there ... I think it works out really well. It’s easy to grab stuff and I hope TheDump gets used that way.”

One of the goals of the association is to keep upgrading the quality of the resources in the various groupings. As teachers from different parts of the State, and in the near future, the Nation, collaborate in identifying appropriate homework materials, they are establishing de-facto educational standards among each other on a grass-roots level.

The impact of LON-CAPA on students and teachers

When we asked the teachers to describe how LON-CAPA has affected their own teaching and their students’ learning, there were some responses that were virtually universal. One very common response concerned the increased level of collaboration (rather than copying) between students. For example:

“...usually you’d see them working on it in pairs, 2 or 3 of them, and particularly the smarter kids who really knew it and liked computers were spending time to sit down with their friends and help them through it ... They were very patient with each other”

Another common response concerned the usefulness of the feedback teachers received via the system concerning student performance. Several teachers commented that they use information from the system to structure review sessions and lesson plans. They also use it to determine whether some students are having particular difficulties with the material. In their words:

“You can access the statistics associated with a problem, and on review days you can say, well they had trouble with these 2 problems; I better just take some time to talk about those.”

And:

“I give them a certain type of problem and if I see a certain percentage of my class getting it wrong then I go ... how I can fix this in the classroom? Or if I have a student that’s consistently getting problems wrong I can pull them aside and say: the test is coming up in a couple days, LON-CAPA told me you don’t get it, let’s sit down and we can go through it again.”

The teachers valued the time saved through the computer grading of homework assignments. They often reported that they were able to spend that extra time helping the students learn. For example, a teacher who didn’t grade assignments himself, but did spend time checking homework in class, reported that:

“What I do now is since we’re not spending as much time checking homework in class, we go through a lot more examples together in class.”

From the students’ perspective, the teachers reported that most students liked the LON-CAPA system, although a few students in every class seem to find it rather disagreeable (perhaps because it disallows copying). As one teacher noted:

“The students appreciate the instant feedback and the opportunity to make multiple attempts at problems they have answered incorrectly. Students told me that CAPA helps them learn the material.”

In conclusion, the teachers we have talked to and with whom we have interacted at a recent workshop [Ref 14] clearly perceive that there is a significant incremental gain in their students learning from using the system, and they believe that these benefits warrant overcoming the startup hurdles. We asked the teachers to summarize what added value LON-CAPA brings to their classrooms, both for themselves and for their students:

- Reduced grading - by not having to grade as much homework teachers can spend more individual time with students.
- Personalized assignments allow students to collaborate on concepts and methods instead of simply sharing answers. Reduces the ability of students to copy homework.
- Specific struggling students can be identified and be given more individualized attention on specific problem spots.
- Immediate feedback allows students correct their mistakes.
- Opportunity for increased communication between the teacher and the students as well as student to student.
- Increases in the opportunities for collaboration between high schools and universities.

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We are especially grateful to the teachers who spent considerable time discussing and sharing their experience with the LON-CAPA system with us, as well as those who have responded to the numerous inquiries and surveys: Kirky Atlee, Fowlerville High School; Mark Beaumann, Grand Ledge High School; Pamela Blamer, Mio AuSable High School; Janet Bronson, Jackson High School; Paul Ciske, Mio AuSable High School; Kathy Ebrahimi, Theodore Roosevelt High School; Jeff Hackborn, Grand Ledge High School; Kim Holberton, Mio AuSable High School; Tim Hoshal, Grand Ledge High School;

George Macklem, Fowlerville High School; David McCreight, Eastern High School; Rob Mock, Beaverton High School; John Plough, East Lansing High School; Michael Sampson, Redford High School.

References

[1] See <http://www.lon-capa.org/>. The site contains information on the system as well as links to numerous presentations and publications.

[2] Kashy, E., Sherrill, B.M., Tsai, Y., Thaler, D., Weinshank, D., Engelmann, M., Morrissey, D.J., *CAPA*, “*An Integrated Computer Assisted Personalized Assignment System*”, Am. J. Phys, Vol. 61, No. 12, 1124-1130 (1993)

[3] The CAPA software was copyrighted by MSU, and provided without fees to the high schools. In 1999, as part of the LON-CAPA collaboration, the software was transformed to GNU general public license.

[4] Deborah A. Kashy, Guy Albertelli, Edwin Kashy and Michael Thoennesen, “*Teaching with ALN Technology: Benefits and Costs*”, Journal of Engineering Education, 499-505 (October 2001)

[5] <http://www.w3.org/History/19921103-hypertext/hypertext/WWW/Proposal.html>
<http://www.w3.org/History/19921103-hypertext/hypertext/WWW/DesignIssues/Multiuser.html>

[6] NSF-ITR 0085921 Project: *Investigation of a Model for Online Resource Creation and Sharing in Educational Settings*
<https://www.fastlane.nsf.gov/servlet/showaward?award=0085921> The RET program based on this project has allowed several teachers to participate each of the past 3 summers.

[7] Geoffrey A Moore, “*Crossing the Chasm*”, HarperCollins, 2002. The HS teachers who used the system in very early beta versions would appreciate the statement on p.31, as these teachers also forgave “...ghastly documentation..., bizarrely obtuse methods of invoking needed functions ...”

[8] From the East Lansing High School physics library, written by John Plough.

[9] Paul Ciske, Mio High School, working with G. Albertelli, MSU, has developed a number of such ‘laboratory calculations checking’ exercises.

[10] Problem by Kathy Ebrahimi, Theodore Roosevelt High School, in collaboration with E. Kashy. MSU, and several other teachers.

[11] Kashy, E., Gaff, S.J., Pawley, N.H., Stretch, W.L., Wolfe, S.L., Morrissey, D.J., Tsai, Y., 'Conceptual Question in Computer-Assisted Assignments', Am J Phys, Vol. 63, No. 11, 1000-1005 (1995). The questions presented here are the MSU physics collection.

[12] For more information, contact the LON-CAPA team at lon-capa@lon-capa.org

[13] P.A. Mabe III and S.G. West, 'Validity of Self-Evaluation of Ability: A Review and Meta-Analysis', Journal of Applied Psychology, 67, (3), p.280 (1982). This meta-analysis aggregating results from 55 published studies, includes several studies relevant to this question.

[14] LON-CAPA Conference and Workshop 2004, 'Exchanging and Sharing Educational Resources', Jan 23-24, 2004, George Washington University, Washington, D.C. See also www.lon-capa.org/presentations/gwuconf.html

About the Authors

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Figures

Figure 1. Illustration of an algorithmic physics problem dealing with torque and equilibrium.

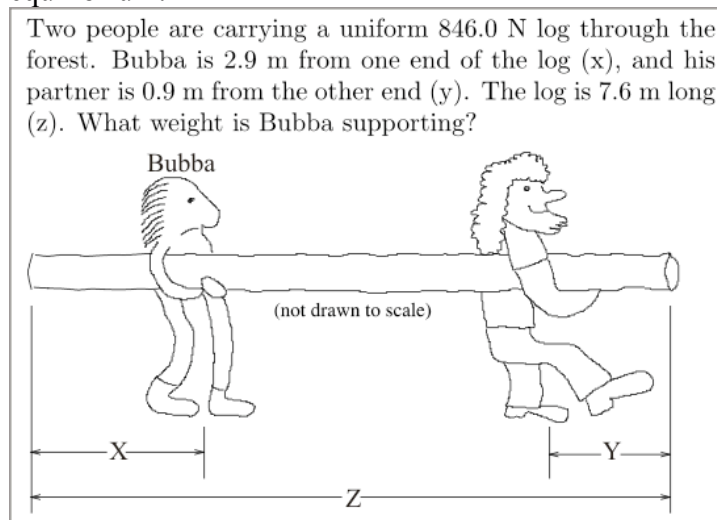
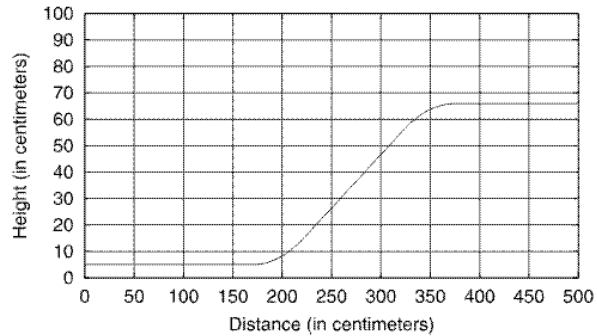


Figure 2. Example of an individualized essay problem. Students see the information displayed in the top section of the figure, and the instructor sees the information in the bottom section to facilitate grading.

The side view of a ramp is shown below. A skateboarder (mass=47.2 kg) with initial speed of 3.37 m/s approaches the ramp. Three students disagree as to whether the skateboarder will reach the top. Judy concludes that she does, Felicia says no, and Terry isn't sure.

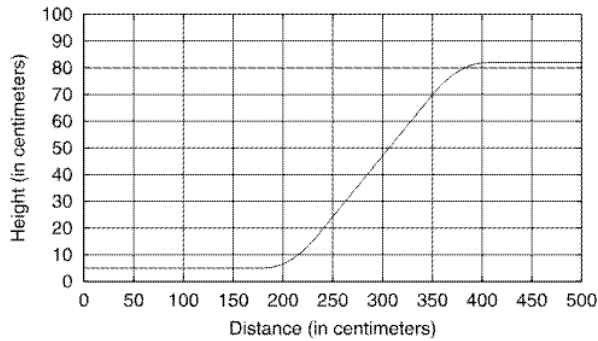


With which student do you agree? Write a short essay to explain how you reached your conclusion. Assume that the skateboarder maintains her position during the climb and that friction is small.

Felicia is correct.
 Skateboarder does not reach the top.
 Calculated values: KE=268, PE=282 (Joules)
 Calculated values: $\frac{1}{2} v^2=5.68$, $gh=5.97$ (m^2/s^2)

Figure 3. Another student's version of the problem shown in Figure 2.

The side view of a ramp is shown below. A skateboarder (mass=59.3 kg) with initial speed of 3.98 m/s approaches the ramp. Three students disagree as to whether the skateboarder will reach the top. Ed concludes that he does, Rob says no, and Carol isn't sure.



With which student do you agree? Write a short essay to explain how you reached your conclusion. Assume that the skateboarder maintains his position during the climb and that friction is small.

Ed is correct.

Skateboarder reaches the top.

Calculated values: KE=470, PE=447 (Joules)

Calculated values: $\frac{1}{2} v^2=7.92$, $gh=7.54$ (m^2/s^2)