LON-CAPA, AN OPEN-SOURCE FREEWARE LEARNING CONTENT MANAGEMENT AND COURSE MANAGEMENT SYSTEM

Gerd Kortemeyer, Wolfgang Bauer

ABSTRACT
The Learning*Online* Network with Computer-Assisted Personalized Approach (LON-CAPA) is a fully integrated cross-institutional learning content management and assessment system initially developed at Michigan State University with a special focus on large-enrollment science and math courses. The underlying cross-institutional content library spans over 40 universities, colleges, and high schools, and allows instructors to share online resources with their peers, and to assemble lessons, chapters, and complete courses from a shared pool of over 60,000 modular learning resources. Besides access to teaching resources, both learners and instructors are provided with immediate detailed feedback on sophisticated online homework and exam problems.

KEYWORDS
Web-based learning, e-learning, virtual learning environment, online assessment

INTRODUCTION

Originally developed at Michigan State University (Kashy et al., 1995; Kortemeyer and Bauer, 1999), the Learning*Online* Network with Computer-Assisted Personalized Approach (LON-CAPA) is open source software that enables instructors to create and/or assemble learning resources.

LON-CAPA is implemented as a geographically distributed network of persistently connected servers at schools, colleges, and universities. Each participating institution needs to contribute at least one server to the network. An institution can set up any number of servers within their domain to scale with increasing workload. Within LON-CAPA, so-designated learning resources are shared among all participating instructors, who can assemble resources from the currently over 60,000 resources in the shared resource pool. Resources can be assembled at different levels of granularity: fragments into pages, pages into pages, pages into modules, etc.

These resources include personalized assignments, quizzes, and examinations with a large variety of conceptual and quantitative problem functionality. In particular, the system provides ample functionality to develop problems which differ from student to student (different numbers, graphs, tables, animations, options, etc), thus encouraging student collaboration on a conceptual level without being able to simply exchange the answers. Feedback from these resources is immediately available, not only to the learner, but also to the instructor (Albertelli, 2002). Besides having tools for formation assessment, LON-CAPA also provides mechanisms for summative assessment, such as bubble-sheet quizzes and exams (Albertelli, 2003). This paper will have particular focus on the assessment capabilities of the system, while at an earlier CBLIS conference, the content sharing features were emphasized (Kortemeyer et al, 2003).

Finally, LON-CAPA is a full-featured course management system, which allows instructors to readily deploy the assembled learning resources, including the assessment resources, in a course. It includes the usual communication, scheduling, template, and grading tools expected from such systems.

LEARNING OBJECTIVES

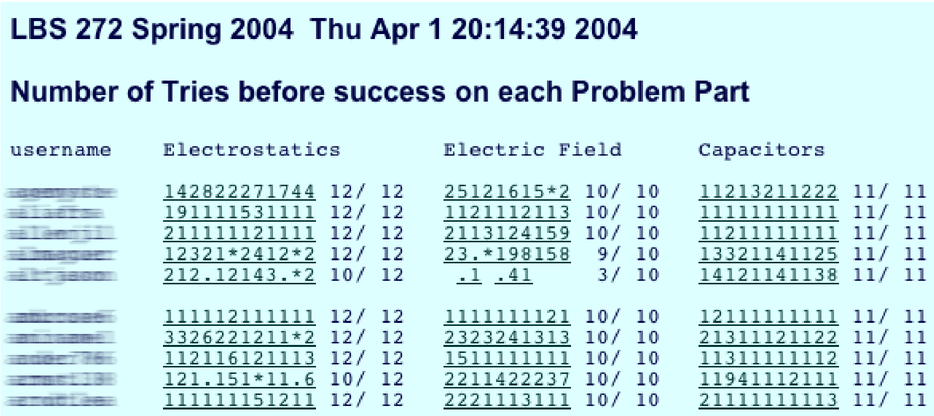
Large enrollment science courses provide a number of challenges to both learners and instructors, and in most situations, the anonymity of such courses leads to a disconnect between instructors and learners on several levels. Learners are confused by the lack of feedback on instructor expectations and their own progress toward them, instructors lack feedback on the actual progress of the learners. High stake exam situations then come as a surprise to both.

LON-CAPA was initially designed to provide constant formative assessment in spite of the challenge of anonymous class settings. While several meta-analyses of the effects of assessment with immediate feedback to the student on their learning are positive (Azevedo and Bernard, 1995; Mason and Bruning, 2003), the range of effect size is considerable (Bonham, Beichner, and Deardorff, 2001) and can even be negative (Bransford, Brown, and Cocking, 2000; Kluger and DeNisi, 1996 and 1998). Even within our own model systems CAPA, Lecture*Online*, and LON-CAPA, when used just for homework, a range of partly contradictory observations were made (Pascarella, 2004; Kotas, 2000).

Over time, LON-CAPA developed into a full-featured learning content management as it became obvious that not only assessment, but also online teaching resources were needed to be integrated in order to address identified needs. With this recognition, the shared resource pool of LON-CAPA was implemented, which today incorporates a variety of teaching resources ranging from simple text pages to complex simulations (Kortemeyer et al., 2001).

INSTRUCTOR FEEDBACK ON FORMATIVE ASSESSMENT

The amount of data gathered from large enrollment courses (in our case, 200-400 students with over 200 randomizing homework problems, each of them allowing multiple attempts), can be overwhelming, and is too diluted to be used unprocessed for effective feedback on learner understanding and their particular misconceptions. LON-CAPA allows instructors to quickly and efficiently analyze this data under a number of different aspects, and to adjust teaching venues accordingly. Fig. 1 shows just a small excerpt of the homework performance in an introductory physics course, students in the rows, problems in the columns, each character representing one online homework problem for one student. A number shown is the number of attempts it took that particular student to get that particular problem correct ("*" means more than nine attempts), "." denotes an unsolved problem, blank an un-attempted problem. This view is particularly useful ahead of the problem deadline, where columns with a large number of dots or blank spaces indicate problems that the students have difficulties with.



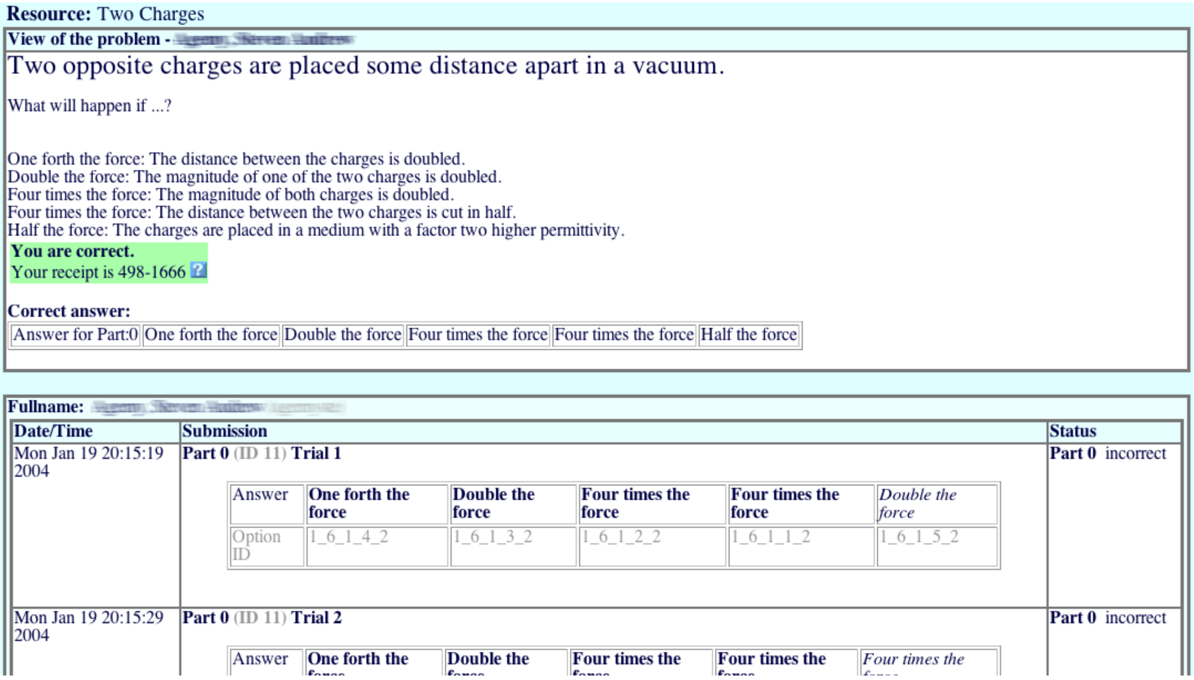
LBS 272 Spring 2004 Thu Apr 1 20:14:39 2004

Number of Tries before success on each Problem Part

username	Electrostatics		Electric Field		Capacitors	
[illegible]	142822271744	12/ 12	25121615*2	10/ 10	11213211222	11/ 11
[illegible]	191111531111	12/ 12	1121112113	10/ 10	11111111111	11/ 11
[illegible]	211111121111	12/ 12	2113124159	10/ 10	11211111111	11/ 11
[illegible]	12321*2412*2	12/ 12	23.*198158	9/ 10	13321141125	11/ 11
[illegible]	212.12143.*2	10/ 12	.1 .41	3/ 10	14121141138	11/ 11
[illegible]	111112111111	12/ 12	1111111121	10/ 10	12111111111	11/ 11
[illegible]	3326221211*2	12/ 12	2323241313	10/ 10	21311121122	11/ 11
[illegible]	112116121113	12/ 12	1511111111	10/ 10	11311111112	11/ 11
[illegible]	121.151*11.6	10/ 12	2211422237	10/ 10	11941112111	11/ 11
[illegible]	111111151211	12/ 12	2221113111	10/ 10	21111111113	11/ 11

Figure 1. A small excerpt of the performance overview for a small introductory physics class

An important task of the feedback tools for the instructor is to help identify the source of difficulties and the misconceptions students have about a topic. There are basically three ways to look at such homework data: by student, by problem, or cross-cutting. For a per-student view, each of the items in the table in Fig. 1 is clickable and shows both the students' version of the problem (since each is different), and their previous attempts. Fig. 2 is an example of this view, and indicates that in the presence of a medium between the charges, the student was convinced that the force would increase, but also that this statement was the one he was most unsure about: His first answer was that the force would double; no additional feedback except ``incorrect'' was provided by the system. In his next attempt, he would change his answer on only this one statement (indicating that he was convinced of his other answers) to ``four times the force'' – however, only ten seconds passed between the attempts, showing that he was merely guessing by which factor the force increased.



Resource: Two Charges

View of the problem -

Two opposite charges are placed some distance apart in a vacuum.

What will happen if ...?

One forth the force: The distance between the charges is doubled.
Double the force: The magnitude of one of the two charges is doubled.
Four times the force: The magnitude of both charges is doubled.
Four times the force: The distance between the two charges is cut in half.
Half the force: The charges are placed in a medium with a factor two higher permittivity.

You are correct.
Your receipt is 498-1666

Correct answer:

Answer for Part:0	One forth the force	Double the force	Four times the force	Four times the force	Half the force

Fullname:

Date/Time	Submission	Status
Mon Jan 19 20:15:19 2004	**Part 0** (ID 11) **Trial 1**	**Part 0** incorrect
Mon Jan 19 20:15:29 2004	**Part 0** (ID 11) **Trial 2**	**Part 0** incorrect

Trial 1:

Answer	**One forth the force**	**Double the force**	**Four times the force**	**Four times the force**	*Double the force*
Option ID	1_6_1_4_2	1_6_1_3_2	1_6_1_2_2	1_6_1_1_2	1_6_1_5_2

Trial 2:

Answer	**One forth the**	**Double the**	**Four times the**	**Four times the**	*Four times the*

Figure 2. Student-centered view of a problem

The per-problem view Fig. 3 shows which statements were answered correctly course-wide on the first and on the second attempt, respectively, the graphs on the right which other options the students chose if the statement was answered incorrectly. Clearly, students have the most difficulty with the concept of how a medium acts between charges, with the absolute majority believing the force would increase, and about 20% of the students believing that the medium has no influence – this should be dealt with again in class.

The simplest function of cross-cutting statistics tools in the system is to quickly identify areas of student difficulties. This is done by looking at the number of submissions students require in reaching a correct answer, and is especially useful early after an assignment is given. A high degree of failure indicates the need for more discussion of the topic before the due date, especially since early responders are often the more dedicated and capable students in a course. Fig. 4 shows a plot of the ratio of number of submissions to number of correct responses for 17 problems, from a weekly assignment five days before it was due. About 15% of the 400 students in an introductory physics course had submitted part or most of their assignment.

The data of Fig. 4 is also available as a table, which in addition lists the number of students who have submissions on each problem. Fig. 4 shows that five of the questions are rather challenging, each requiring more than 4 submissions per success on average (for example, problem 1 requires a double integral in polar coordinates to calculate a center of mass). Note that an error in the unit of the answer or in the formatting of an answer is not counted as a submission – in those instances, students re-enter their data with proper format and units, a skill that students soon acquire without penalty.

Foil Number	Foil Name	Foil Text	Correct Value
1	1_6_1_1_2	The distance between the two charges is cut in half.	Four times the force
2	1_6_1_2_2	The magnitude of both charges is doubled.	Four times the force
3	1_6_1_3_2	The magnitude of one of the two charges is doubled.	Double the force
4	1_6_1_4_2	The distance between the charges is doubled.	One forth the force
5	1_6_1_5_2	The charges are placed in a medium with a factor two higher permittivity.	Half the force

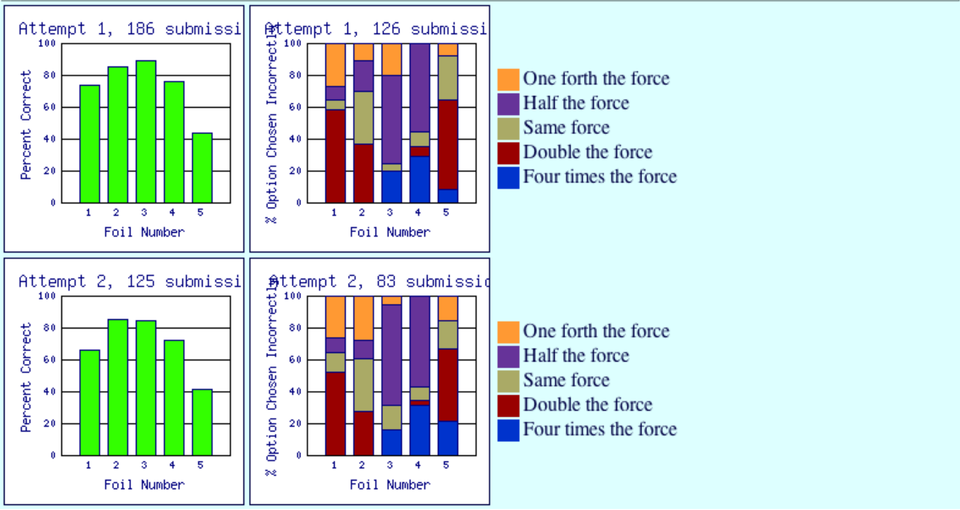


Figure 3. Compiled student responses to a problem

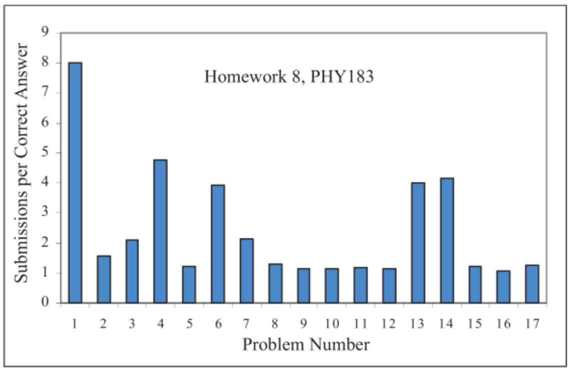


Figure 4. One early measure of a degree of difficulty

EVIDENCE OF SUCCESS

The ultimate measure of success for our system is whether it indeed proves to be an effective tool in increasing educational outcomes for students. A number of systematic studies, conducted primarily within undergraduate physics courses, suggest that LON- CAPA can have a pronounced impact on student learning. Unfortunately, in recent years we have not been able to conduct “before/after” studies anymore, since all introductory physics courses at Michigan State University by now use LON-CAPA.

One study (Kashy, 2001) followed an introductory calculus-based physics course from the years before system implementation until late into its deployment. In the years before using LON-CAPA, the final grade distribution exhibited the traditional bell shape around a grade of 2.5, with relatively few students receiving grades of 3.5 or 4.0. After the move to LON-CAPA, the proportion of students earning a grade higher than 3.0 increased dramatically, see Figure 5. Notably, independent evaluators judged that the examinations used in the course after deployment were more challenging than those used in earlier years, and so the positive change in educational outcomes cannot be attributed to a lowering of standards for the class.

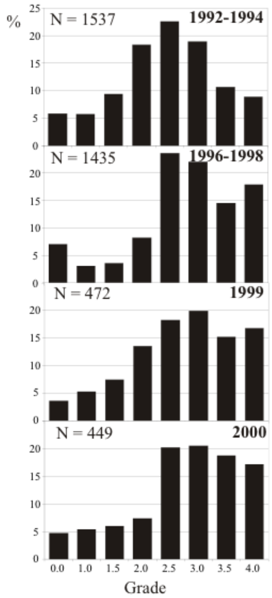


Figure 5. Final grade distribution in an introductory physics course before (1992-1994) and after introduction of online homework (1996 and later).

Two other studies (Kashy, 2001) suggest that LON-CAPA may increase the participation and success of women in the sciences. One study focused on a yearlong physics course for non-science-majors, in which the system was used only during the second semester. Figure 6 shows the final grade distribution for both men and women in the first semester (no online homework) and the second semester (with online homework). Final grades from the second semester indicated that women were especially likely to benefit from the system. The second study indicated that women, who began the course significantly less well prepared than men, improved their performance relative to men across the semester until there were no gender differences by the final exam.

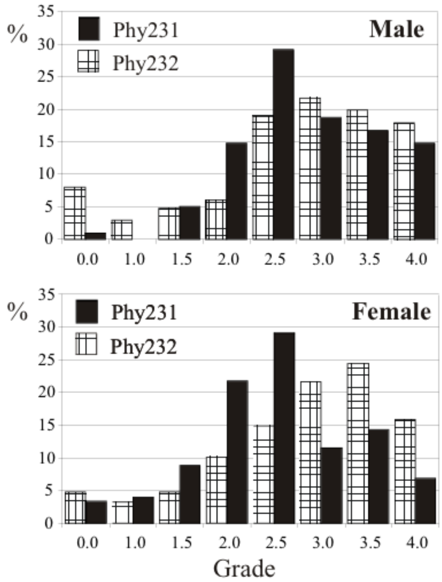


Figure 6. Final grade distribution in an introductory physics course for men and women. The first semester (Phy231) did not use online homework, the second semester (Phy232) did.

Why online homework appears to be more beneficial for female students is not yet understood. In a recent study, though, we found that women make different use of the ability to have multiple tries for getting a homework correct: men report that multiple tries are leading them to "guessing" behaviour, while women state that multiple tries encourage them to persist.

A majority of students, typically 80%, consider that LON-CAPA helps them learn and understand the course material. That this does not lead to frustration is surprising, since according to several self-evaluative studies, the time students spend working on assignments and other course requirements has increased by nearly a factor of two. Figure 7 shows a histogram of self-reported additional hours spent per week on task doing homework versus perceived helpfulness of the system. It is remarkable that some students report having spent ten additional hours on homework, yet find the system helpful. Unfortunately, there are also students who worked significantly longer on homework and did not find the time well spent.

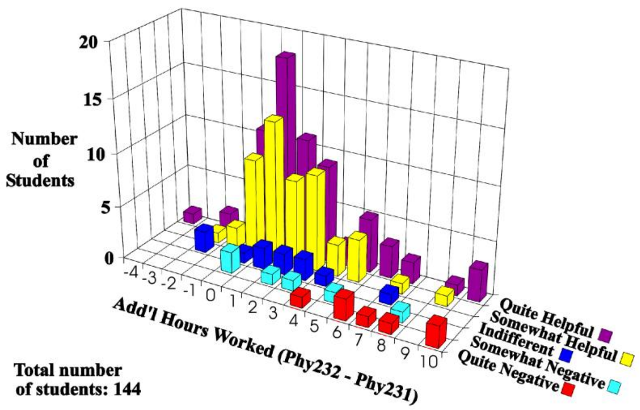


Figure 7. Histogram of self-reported additional hours per week spent on task doing online homework versus perceived helpfulness of the system

SUSTAINABILITY

An open-source freeware system naturally does not derive any income from license fees, and while the open-source model promises community-based sustainability from the contributions of its members, in reality, most of the coding is still done at MSU. Including its predecessor systems, LON-CAPA has been supported by Michigan State University for over 12 years – longer than any commercial system has been around.

There are no financial incentives for faculty to participate, but the user community on campus and nationwide has seen a steady growth over the years, most likely due to the favourable effect/effort-ratio, particularly when faculty start out using only resources already produced by other faculty. Some faculty at a later point start developing and sharing their own resources, others continue to be a "consumer."

Campus administrators frequently point out that the academic world is not ready for the current content sharing model, and in several disciplines, most notably the humanities, this is likely true. Yet in introductory science and mathematics courses, we have found a ready willingness of faculty to share their materials, most likely because the standardization and introductory character of the curriculum prevents the "not-invented-here" phenomenon from interfering, and most instructors are proud to the LON-CAPA usage count of their material go up, where it otherwise would have no market or particular individual intellectual value.

REPLICABILITY

We currently have over 20 universities and colleges and an equal number of schools as part of our network, which are sharing online science and math resources with each other, as well as make limited contributions to the code base. These institutions have been using LON-CAPA extensively in their courses, several of them for years, including the predecessor CAPA program.

LON-CAPA is open-source freeware, and can be downloaded and installed under the GNU General Public License. Running the system, though, is not for free, since it requires local support and expertise. We have addressed dissemination to institutions, which are unwilling or unable to provide local support, through the creation of a commercial hosting company.

CONCLUSIONS

Technology does indeed provide means to get considerable feedback on many aspects of teaching and learning. To make good use of that feedback is a far greater challenge. We have been using LON-CAPA for both formative and summative assessment. Our ability to detect, to understand, and to address student difficulties is highly dependent on the capabilities of the tool. Feedback from numerous sources has considerably improved the educational materials, which is a continuing task. Analysis mechanisms like the ones provided by LON-CAPA can facilitate research in physics education. Finally, as a result of feedback on students' work, those doing very poorly can be identified quite early.

The single-most effective outcome of using online homework systems is that students are spending additional meaningful time-on-task. The majority of the students in our courses find this time well spent and are considering the system to be "very helpful." Students who would traditionally be found in the 26-50% quartile of a course appear to benefit the most from the use of the system, with a significantly higher impact for women.

More work remains to be done in analyzing online behaviour of students, in particular regarding early identification regarding students at risk. Also, student online discussions around homework offer a rich area of research, as they allow insights into problem-solving strategies.

REFERENCES

Albertelli, G., Minaei-Bidgoli, B., Punch, W. F., Kortemeyer, G., and Kashy, E. (2002). Concept Feedback in Computer-Graded Assignments, Proc. IEEE Frontiers in Education 32.

Albertelli, G., Kortemeyer, G., Sakharuk, A., and Kashy, E. (2003), Personalized Examinations in Large On-Campus Classes, Proc. IEEE Frontiers in Education 33.

Azevedo, R., and Bernard, R. M. (1995). A Meta-analysis of the Effects of Feedback in Computer-based Instruction, J. Educ. Comp. Res. 13, 111-127.

Bonham, S., Beichner, R., and Deardorff, D. L. (2001). Online Homework: Does It Make a Difference?, Phys. Teach. 39(5), 293.

Bransford, J. D, Brown, A.L., and Cocking, R. R. (Eds) (2000). How People Learn: Brain, Mind, Experience, and School, Washington, D.C.: National Academy Press

Kashy, D. A., Albertelli, G., Kashy, E., and Thoennessen, M. (2001). Teaching with ALN Technology: Benefits and Costs, J. Eng. Educ. 90 (4), 499 .

Kashy, E., Gaff, S. J., Pawley, N., Stretch, W. L., Wolfe, S., Morrissey, D. J., and Tsai, Y. (1995). Conceptual Questions in Computer-Assisted Assignments, Am. J. Phys, 63(11), 1000.

Kluger, A. N., and DeNisi, A. (1996). The Effects of Feedback Interventions on Performance: Historical Review, a Meta-Analysis and a Preliminary Feedback Intervention Theory, Psyc. Bull. 119, 254-284.

Kluger, A. N. , and DeNisi, A. (1998). Feedback interventions: Toward the understanding of a double-edged sword, Cur. Dir. Psyc. Sci. 7, 67.

Kortemeyer, G., and Bauer, W. (1999). Multimedia Collaborative Content Creation (mc^3) - The MSU LectureOnline System", J. Eng. Educ. 88 (4), 405.

Kortemeyer, G., Albertelli, G., Bauer, W., Berryman, F., Bowers, J., Hall, M., Kashy, E., Kashy, D., Keefe, H., Minaei-Bidgoli, B., Punch, W., Sakharuk, A., and Speier, C. (2003). The LearningOnline Network with Computer-Assisted Personalized Approach, Computer Based Learning in Science Conference, Nicosia, Cyprus.

Kortemeyer, G., Bauer, W., Kashy, D. A., Kashy, E., and Speier, C (2001), The LearningOnline Network with CAPA Initiative", Proc. IEEE Frontiers in Education 31, see also http://www.lon-capa.org/.

Kotas, P. (2000). Homework Behavior in an Introductory Physics Course, Masters Thesis (Physics), Central Michigan University

Mason, B., and Bruning, R. (2003). Providing Feedback in Computer-based instruction: What the Research Tells Us." http://dwb.unl.edu/Edit/MB/MasonBruning.html.

Minaei-Bidgoli, B., Kashy, D. A., Kortemeyer, G., and Punch, W. F. (2003), Predicting Student Performance: An Application of Data Mining Methods with an educational Web-based System", Proc. Frontiers In Education 33.

Pascarella, A. M. (2004). The Influence of Web-Based Homework on Quantitative Problem-Solving in a University Physics Class, Proc. NARST Annual Meeting

Thoennessen, M., Kashy, E., Tsai, Y., and Davis, N. (1999). Impact of Asynchronous Learning Networks in Large Lecture Classes, Group Discussion and Negotiation 8, 371 and private communication.

Gerd Kortemeyer
E-193 Holmes Hall
Michigan State University
East Lansing, MI 48824
Email: korte@lon-capa.org

Wolfgang Bauer
4208 Biomedical Physical Sciences
Michigan State University
East Lansing, MI 48824
Email: bauer@pa.msu.edu