

# RESEARCH ON LEARNING IN LON-CAPA: MULTIPLE CONTENT REPRESENTATIONS, TEST DATA BANKS

Wolfgang Bauer, Gerd Kortemeyer

## 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. Architecturally, it is based on a cross-institutional and cross-disciplinary content library out of which instructors can select and sequence learning content including sophisticated online homework and exam problems. The paper discusses new avenues for content management, which are opening up once that a course management system leaves the “course container.”

## KEYWORDS

Web-based learning, e-learning, virtual learning environment, content management, objective testing

## INTRODUCTION

Originally developed at Michigan State University (Kashy et al., 1995; Bauer et al., 1996, 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. 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 and sequenced at different levels of granularity: fragments into pages, pages into pages, pages into modules, etc.

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. This paper will have particular focus on the content management and sequencing capabilities of the system, both current and future, while at an earlier CBLIS conference, the existing content sharing features were emphasized (Kortemeyer et al, 2003).

## CONTENT POOL ORGANIZATION

The majority of course management systems are built around the course as the main entity, and learning content is then uploaded to the courses. At the end of the semester, most systems allow to export the content to an instructor’s personal computer, and then to re-upload it in another semester. Within LON-CAPA, content is stored independent of a specific course in a shared cross-institutional content pool. Figure 1 shows a top-level view of the resource pool while browsing. At the top-level, the resource pool is organized by so-called domains, which correspond to education institutions (currently over 20 universities and colleges, as well as over 20 high and middle schools) and publishing companies, and at the next level by authors within the domain. Below that level, the organization is the author’s responsibility.

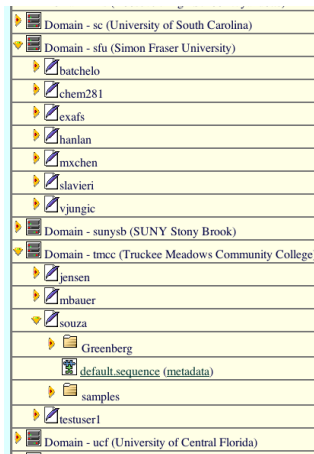


Figure 1. Except of the current LON-CAPA content resource pool in “Browse” mode

Physically, the authoritative copies of the resources are distributed across the networked servers located at the participating institutions. To provide scalability, share load, and avoid single points of failure, content is dynamically replicated across the network. Figure 2 shows the URL of a resource in the network, in this case by an author collaboration “mmp” (“Multimedia Physics”) at MSU (Michigan State University), but accessed from a server located at North Dakota State University.



Figure 2. URL of a content resource

Copyright for the resources stays with the authors. Access rights (rights of use) to content resources can be managed at different levels. The default setting for a content resource is that any participating instructor can select it for any course in the network, and then in turn, the students of that course have access. But authors can choose any other mechanism and restrict access at different levels down to the level of an individual course (Figure 3, left). In addition keyed access mechanisms to courses are provided to enable e-commerce functionality (Figure 3, right) – even though fully implemented, this feature has not yet been used.

Edit action	Effect	Domain	Course	Section/Group
<input type="text"/>	deny	Default		
1. <input type="text"/>	allow	msu	<input type="text"/>	<input type="text"/>
				Select Course
2. <input type="text"/>	allow	fsu	14837df9f9b408dfsu12	<input type="text"/>
			PHY 2048C - General Physics A Summer 2004	Select Course
Store				

**Enter Access Key to Unlock this Course**

7f8-8727-f68d

Figure 3. Custom access rights (left) and keyed course access (right)

As the resource pool grows, selecting an appropriate content resource becomes an increasingly challenging task. In addition to the “Browse” view of the resource pool, instructors can search the cataloguing information. LON-CAPA has two categories of cataloguing or metadata (“data about data”) mechanisms: static metadata provided by the authors, such as title, subject, keywords, etc, and dynamics metadata, gathered by the system based on the use of the resource.

These metadata streams are used in similar ways that the Google search engine classifies documents that match search terms: the more often a document is linked to, the higher it climbs in the hierarchy. For the same reason LON-CAPA provides educators with information on use of any given resource by other educators, see Figure 4.

Access and Usage Statistics	
Network-wide number of accesses (hits)	890
Number of resources using or importing resource	1 <ul style="list-style-type: none"> <li>• <a href="#">Eukaryotic Gene Control [asn/bio/Gene_Errpr/111#09GeneCtr1_sequence]</a></li> </ul>
Number of resources that lead up to this resource in maps	1 <ul style="list-style-type: none"> <li>• <a href="#">Back to the Original Question [asn/bio/Gene_Errpr/problems/originalquestion_problem]</a></li> </ul>
Number of resources that follow this resource in maps	1 <ul style="list-style-type: none"> <li>• <a href="#">Eukaryotic vs Prokaryotic Gene Expression II [asn/bio/Gene_Errpr/problems/eukvsprokII_problem]</a></li> </ul>
Network-wide number of courses using resource	3 <ul style="list-style-type: none"> <li>• LBS 145 - Spring 2004</li> <li>• ZOL 341 - Fall 2003</li> <li>• BS 111 - Fall 2003</li> </ul>

Figure 4. Dynamic Metadata, Context

## MULTIPLE CONTENT REPRESENTATIONS

Hundreds of studies have been published, in which different approaches and methodologies to education, as well as different implementations of technologies in the delivery of educational materials have been studied. Overwhelmingly, authors find no statistically significant benefit in employing any given technological innovation (Russel, 1999). One may speculate that this may have many reasons. Some of this effect may be explained in the lack of sufficiently sensitive or accurate measuring tools. Even standardized conceptual tests, such as the “Force Concept Inventory” (Hestenes, 1992, 1995) that is ubiquitously used to measure effectiveness in physics education innovation, may not necessarily be in perfect alignment with the learning objectives that a technological innovation was intended to achieve.

However, more likely, there is not any one form of content delivery or technological innovation that is suited for all learners. One may hypothesize that the dispersion in individual learning styles may be too large for any given innovation to have a statistically significant influence on the average success. To remedy this problem, we may offer multiple content representations to a group of learners, ideally allowing each to find their own customized optimized match to their preferred learning style.

In addition, a learner is not an inanimate machine or system for which one can change the boundary conditions and measure a difference in learning outcome in a straightforward way. Instead, any student knows when she/he has achieved a grasp of a subject under study. A dedicated learner will employ multiple learning aid, models, and techniques until he or she is satisfied with the result. This inherent feedback loop complicates all attempts to measure success for any given innovation. And to be fair, additional complications come from any student at the other end of the spectrum in a class who simply does not care! However, offering multiple representations offers the hope that students who want to learn will be able to spend more meaningful time on task, and that students who are not engaged by traditional means of delivery find ways to connect with the subject matter.

While until the mid-90s, the notion of different learner types (i.e., auditory, visual, textual) was under investigation, more recent studies (Bransford, Brown, and Cocking, eds., 2000) suggest that learners are not of a specific type themselves, but rather benefit from different representations in different contexts, and may often require more than one representation of a certain scenario, in spite of the fact that novices frequently encounter difficulties in the translation between different representations. These findings need to result in a refined understanding of “multiple content representation” (i.e., communication of the same concept in for example text, graphics, simulations, movies, etc), away from something that is pre-selected for a certain learner according to preferences or cognitive pre-tests, and toward a far more complex, dynamic, adaptive construct of appropriate resources shifted in and out of scope.

LON-CAPA allows for the insertion of dynamic branch points into learning sequences. At branch points, the system has access to any of the student’s data from within the course, as well as all student preferences.

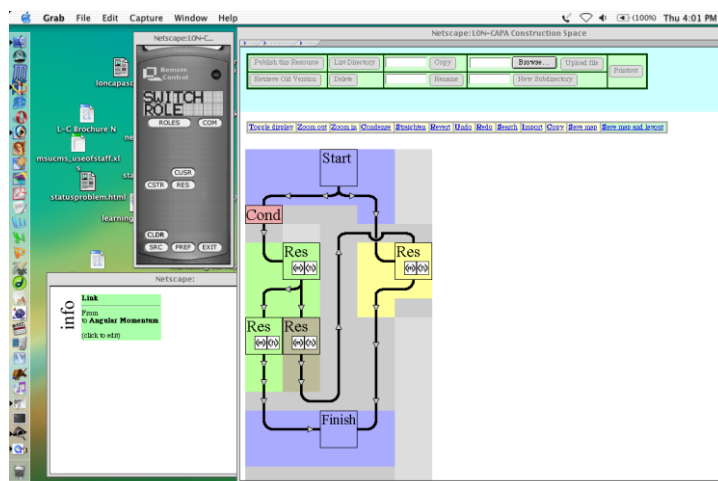
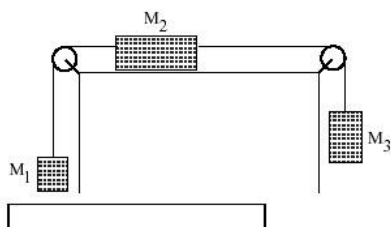


Figure 5. Resource Assembly Tool, Branching

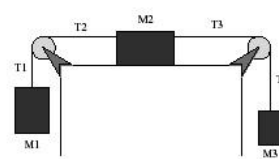
## RESULTS FROM USING MULTIPLE CONTENT REPRESENTATIONS OF FORMATIVE ASSESSMENT PROBLEMS

A strength of the LON-CAPA system is its ability to support a wide variety of problem types and functionality, and approximately half of the shared content pool are assessment questions. Figure 6 shows two problem representations of the same concepts, one as a numerical problem, one as conceptual multiple-choice multiple-response.

The three blocks shown are released at  $t=0$  from the position shown in the figure. Assume that there is no friction between the table and  $M_2$ , and that the two pulleys are massless and frictionless. The masses are:  $M_1 = 1.0$  kg,  $M_2 = 7.0$  kg,  $M_3 = 3.0$  kg. Calculate the speed of  $M_2$  at a time 1.55 s after the system is released from rest.



In the figure,  $M_2$  has more mass than  $M_1$  and  $M_1$  has more mass than  $M_3$ . The questions refer to the magnitudes of tensions and weights.



There is friction between the horizontal plane and  $M_2$  ( $\mu_k \neq 0$ ).  $M_2$  is observed to travel at a constant speed. Assume that the pulleys are frictionless and have negligible mass. Select the appropriate statements to complete the following sentences.

Choices: True, False, Greater than, Less than, Equal to.

1.  $T_3$  is ...  $T_2$ .
2.  $T_1$  is ...  $M_1g$ .
3.  $T_4$  is ...  $M_3g$ .
4.  $T_2$  is ...  $T_1$ .
5. The magnitude of the net force on  $M_2$  is  $T_2 - T_3$ .
6.  $M_1$  accelerates downwards.

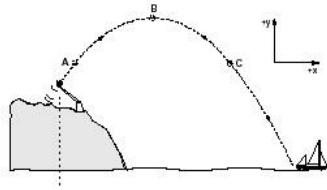
Figure 6. Different problem representations of the same concept

In addition, problems can be posed that require representation translation, see Figure 7 as an example. In problems of this type, students need to take an alternative representation of data (in this case a graph) and translate it into numerical values that can be used for calculations.

Two studies were conducted by the LON-CAPA collaboratio to explore the effects of multiple problem representations. One small-scale study (Kashy, 2001) determined the correlation between performance on certain problem types and final exam grades, and found a significantly stronger correlation for problems requiring representation translation than for conventional problems.

**Catapult**

A catapult on a cliff launches a large round rock towards a ship on the ocean below. The rock leaves the catapult from a height  $H$  of 32.0 m above sea level, directed at an angle  $\theta$  above the horizontal with an unknown speed  $v_0$ .



The projectile remains in flight for 6.00 seconds and travels a horizontal distance  $D$  of 142.0 m. Assuming that air friction can be neglected, calculate the value of the angle  $\theta$  (in degrees).

Tries 0/99

Calculate the speed at which the rock is launched.

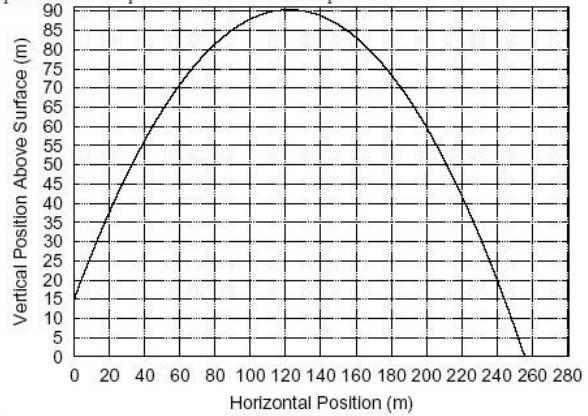
Tries 0/99

To what height above sea level does the rock rise?

Tries 0/99

**Trajectory of a rock on planet-X**

The trajectory of a rock thrown from a height with an initial speed of 22.9 m/s is shown in the figure below. Evaluate the magnitude of the gravitational field at the surface of the planet. The planet has no atmosphere.




Tries 0/99

Figure 7. Two problems addressing the same concept, one requiring representation translation

A second study, which is still in progress, analyses the character of online discussions around different problem types. In LON-CAPA, separate threaded discussions are directly attached to each online problem, which allows it analyse these online discussions in the context of a certain problem, and correlate findings with characteristics of the problem. Since the problems are randomized in the sense that different students see different numbers or concept statements, these discussions cannot simply consist in exchanging answers, and since the grades in the analyzed courses are not “curved,” students are almost surprisingly willing to help each other: a total of 3394 discussion contributions was associated with the 497 analyzed problems. It was found that problem type and difficulty can have profound impact on the character of the online discussions.

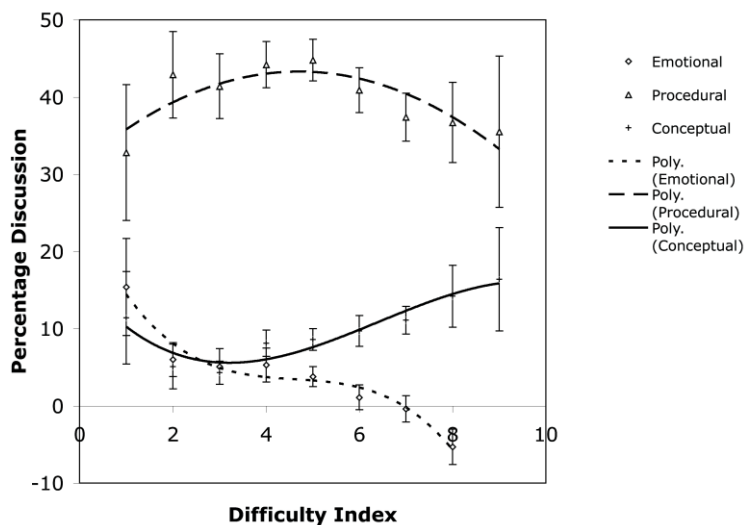


Figure 8. Discussion characteristics versus problem difficulty

Multiple-choice type questions that do not require numerical calculations are often referred to as “conceptual problems,” yet the results of the study do not show an increased prominence of discussion entries on a conceptual level. Instead, in comparison to numerical questions, more discussion entries are simply focussed on what the solution *is*, rather than how to determine it. Increased conceptual discussion activity was only found around ranking-type problems, yet the sample size of these questions was far too small (5 out of 497 analyzed questions) to make general predictions.

The same concept can also be addressed with questions of different degrees of difficulty. Figure 8 shows the prominence of different online discussion classes as a function of problem difficulty. Shown is the percentage prominence of procedural and conceptual discussions around problems with a given difficulty index, ranging from “0” (every student gets the problem correct on the first attempt) to “10” (no student can solve the problem). As can be seen from the error bars, beyond a difficulty index of 5, the increase of conceptual discussions is non-significant. The third set of data tracks positive and negative emotional discussion entries around the problem. As can be seen, starting around a difficulty index of 5, students become rapidly more unhappy with the problem, and beyond an index of 7, negative outweigh positive comments. If among other things, formative problems are meant to spur conceptual discussions, beyond mid-range problem difficulty, there is just significantly more pain for non-significant gain.

### TESTBANKS

As discussed above, the LON-CAPA software is able to collect meta-data on degree of difficulty, degree of discrimination, frequency of use, as well as student perception on the effectiveness of each individual testing resource in multiple contexts.

Figure 9, left side, shows the user interface that is presented to learners and that enables them to submit subjective evaluation data. For each of the statements presented the user can select simple responses from a pull-down menu, ranging from “strongly disagree” (1) to “strongly agree” (5). An educator wishing to utilize a given resource is able to look up the metadata on statistical assessment and evaluation, as shown in the right side of Figure 9. Individual comments are only visible to the author of the resource. The comments shown here were actual student responses, and we blacked out their user-ids for privacy reasons.

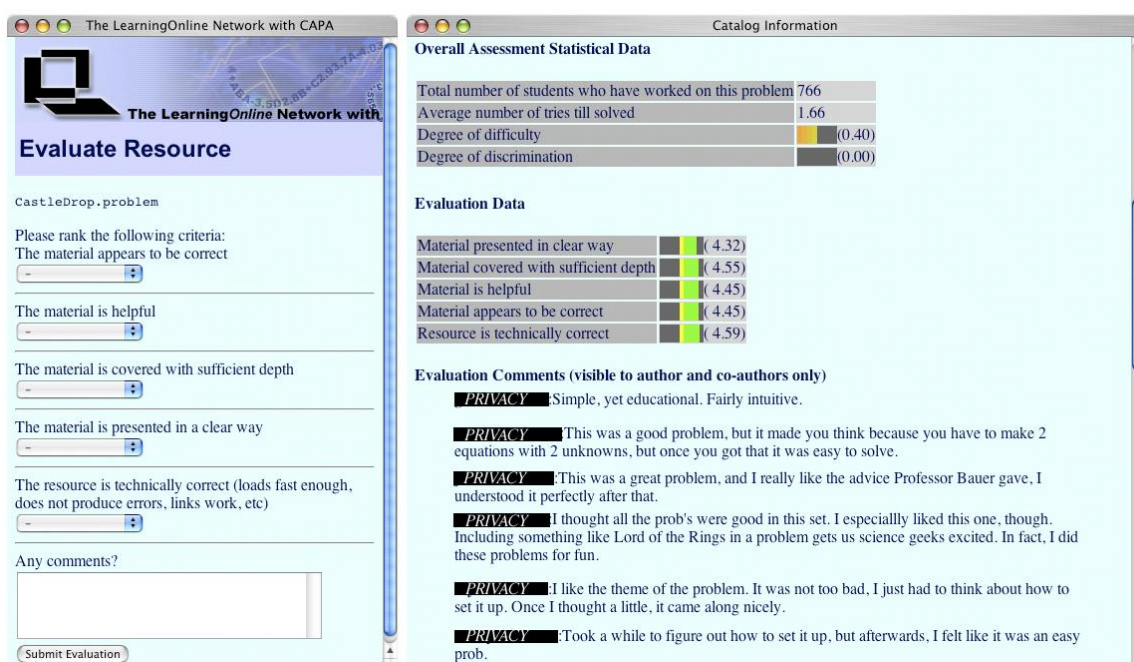


Figure 9. Left side: user interface used by LON-CAPA to collect user evaluation data; right side: excerpt from the summary information metadata presented to the resource creator.

Any instance in which a given resource is used in an exam setting thus collects information on degree of difficulty and discrimination. This information can be archived and used to create random tests that are generated from a large bank of testing resources. The computer can then create tests that do not rely on the selection of the instructor, but instead allow for a comparison relative to an objective standard. This is true in particular when one allows for creation of individual tests for students, in which the questions are allowed to vary from student to student.

This approach accomplishes several objectives:

- Any learning and teaching innovation can be tested in an objective way against a very large collection of test items; this collection can be so large that a contamination of the results due to leaking of information is impossible, which is in marked contrast to standardized tests like the SAT, for example, or even the venerable Force Concept Inventory, which have to be closely guarded for fear of compromising outcomes.
- Any given instructor can be evaluated against an objective standard. As the ability to “teach to the test” is removed, the true effectiveness of the teacher in the classroom can be gauged much more effectively. Since teaching evaluation is an increasingly important component of the evaluation of faculty, at least in US public universities, this approach offers a novel contribution towards a more objective evaluation of teaching.
- The teacher is not the judge any more: since the instructor does not know which questions will enter the computer selection for the exams from the test bank, he or she is not in the position of judging the students’ performance any more. This way the old question, “Is this going to be on the test?” is becoming meaningless. Learners and teachers become a team with a common goal: maximize performance of the class as compared to a standardized and more objective measurement tool.
- Since all educators can contribute to the test bank, they are not forced into a passive consumer role any more, as is the case with current standardized tests administered, for example, by the US Department of Education under the “No Child Left Behind” act.

## CONCLUSIONS

The LON-CAPA course management software has reached a state of maturity and its resource pool has reached a size that now allows novel approaches to old problems. With over 60,000 individual resources, with many tens of thousands of students enrolled each semester at approximately 50 institutions, with automated metadata collection, and with resource sharing across the LON-CAPA member network we have entered a new phase in the use of educational technology. It has now become possible to think about multiple content representations to provide a more customized accommodation of individual learning styles.

In the case of online formative assessment problems, it could be demonstrated that mastery of different problem representations correlate differently with exam success, and that different problem types and difficulties lead to different online discussion behaviour.

In addition, we are now in the position to establish more objective measurement tools for learning outcomes that utilize large test banks of individual test items for which standardized statistical information has been collected across many educational settings.

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

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