Teaching and Learning in the 21st Century

Wolfgang Bauer

Michigan State University
“I think, however, that there isn’t any solution to this problem of education other than to realize that the best teaching can be done only when there is a direct individual relationship between a student and a good teacher [...] It is impossible to learn very much by simply sitting in a lecture [...] But in our modern times we have so many students to teach that we have to try to find some substitute for this ideal.”

Richard P. Feynman, June 1963
(Introduction to Feynman Lectures)
Potential Problems in Large Lecture Classes

- Large spread in preparation of a diverse student population
- Impersonal nature of instruction / little one-on-one contact between instructor and students
- Achieving and maintaining high standards
- Large human resources required for grading
- Timely recognition of students' problems and difficulties
- Cheating on exams/Copying assignments
Technology Teaching Innovations

Gutenberg Press
~1450

Radio
~1900

Television
~1930
Internet

- First web-browser

Tim Berners-Lee, CERN, 1989
Moore’s Law

- 1947: Transistor is invented
- 2006: Each Intel CPU chip has $\sim 10^8$ transistors
- This year, $\sim 100$ quadrillion transistors will be produced

Microchips double in power and halve in price every 18 months

Gordon Moore
Growth of Internet

- Number of Internet hosts doubles every year
- Right now: 1 Internet host for every ten humans

Data:
http://www.isc.org/
What are the universities with the biggest enrollments in the United States, Great Britain, Germany?
How big is the University of Phoenix?

U. of Phoenix Buys Naming Rights to a Pro-Football Stadium

By Goldie Blumenstyk

Following in the path of Gillette, FedEx, and Reliant, the University of Phoenix has bought the naming rights to a National Football League stadium, it announced on Tuesday.

Phoenix's $154-million, 20-year deal with the Arizona Cardinals makes it the first university to...
- Learning Content Management System
- Assessment System
- Multiple Content Representations
- Research on Learning
- Open-Source
- Learning Content Management System
- Assessment System
- Multiple Content Representations
- Research on Learning
- Open-Source
LON-CAPA

- Merger of three large instructional technology systems at MSU
  - CAPA – homework system since 1992
  - MuliMedia Physics – cd-based learning system since 1992
  - LectureOnline – web-based course management system
- Learning Online Network with Computer-Assisted Personalized Approach
LON = LearningOnline Network (1)

- Providing high quality learning content in an online environment is time and cost intensive
- Typical scenario today:
  - Online material is developed by only one instructor
  - Online material is used by only one instructor
  - Online material is used in only one course
  - No assessment of learning effectiveness
- Ineffective use of time and resources
Much better scenario:

- Online material is developed and reviewed by more than one instructor
- Online material is shared among instructors
- Online material gets used across many courses and disciplines
- Continual assessment of learning effectiveness
LON = LearningOnline Network (3)

- We have built:
  - a cross-institutional cross-disciplinary content repository
  - a tool to seamlessly assemble this content
  - a course management system to readily deploy this content and courses built on it
Network

- Network of connected servers
- Any server in the network can serve sessions for any user
- Content replication in background
- Network-wide persistent URL paths
- Essentially unlimited scalability

http://neptune.physics.ndsu.nodak.edu/res/msu/mmp/kap18/problems/cd
Virtual Filesystem

“The aisles of your supermarket”

Your shopping cart: The Resource Assembly Tool
Sample Resources
Search

- **Statics metadata**: Dublin Core, cross-walk to IMS
- **Dynamic metadata**: use assembly data for recommender system:

## Access and Usage Statistics

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<th>Value</th>
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<td>Network-wide number of accesses (hits)</td>
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<td>Number of resources using or importing resource</td>
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<td>Number of resources that lead up to this resource in maps</td>
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<td>Number of resources that follow this resource in maps</td>
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<td>Network-wide number of courses using resource</td>
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## Assessment Statistical Data

- Total number of students who have worked on this problem: 291
- Average number of tries till solved: 1.37
- Degree of difficulty: (0.36)
Custom Rights

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Each author can determine for each individual resource or a group of resources which group of users has what set of usage rights under which conditions!
LearningOnline Network

- Oct. 2006 snapshot of resource pool

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- Biology, physics, chemistry, math, food science, geology, economics, …
LON-CAPA use at MSU

MSU Course Codes versus Enrollment

- CEM: 24%
- BS: 13%
- CSE: 12%
- ZOL: 10%
- ACC: 3%
- ADV: 3%
- BMB: 1%
- LBS: 4%
- MTH: 1%
- LBS: 1%
- ISB: 11%
- ISP: 11%
- PHY: 12%
- PSY: 2%
- STT: 1%
- TE: 1%
- RET: 3%
- STT: 3%
- ENT: 0%
LON-CAPA use at MSU

Number of Courses per Semester at MSU

- CAPA
- LectureOnline
- LON-CAPA
- Total


W. Bauer, October 2006, UC Berkeley
LON-CAPA use at MSU

CAPA/LectureOnline/LON-CAPA
Student Course Enrollments per Semester at MSU

- CAPA
- LectureOnline
- LON-CAPA
- Total

- 2 per. Mov. Avg. (CAPA)
- 2 per. Mov. Avg. (LectureOnline)
- 2 per. Mov. Avg. (LON-CAPA)
- 2 per. Mov. Avg. (Total)

Number of Student Course Enrollments

Semester

Some of the most prominent options for instructional technology (according to Freeman Publishers)

10. Are you using media in any of your classes?
- Yes
- No

11. If so, what are you using?
- Please check all that apply:
  - PowerPoint presentations
  - Encouraging students to research on the web
  - Textbook’s companion website
  - E-books
  - Clickers (student response systems)
  - LonCapa
  - MasteringPhysics
  - WebAssign
  - eGrade
  - iSolve
  - Physics Now
  - Blackboard
  - WebCT
  - Other: [ ]
- Learning Content Management System
- Assessment System
- Multiple Content Representations
- Research on Learning
- Open-Source
CAPA

- **Computer-Assisted Personalized Approach**
- Online assessment with immediate feedback and multiple tries
- Different students get different versions of the same problem
  - different options
  - different graphs or images
  - different numbers or formulas
A crate with a mass of 177.5 kg is suspended from the end of a uniform boom with mass of 88.5 kg. The upper end of the boom is supported by a cable attached to the wall and the lower end by a pivot (marked X) on the same wall. Calculate the tension in the cable.
CAPA

Benefits:

• learners can work together without just exchanging the answers
• learners get immediate feedback on their learning progress
• instructors get immediate feedback on their learners’ progress
• in-class audience feedback systems (IR, RF, PDAs, ...) fully integrated
Benefits, cont.:

- cost-savings in routine grading
- instructor time used for instruction (possibly even one-on-one; see Feynman quote!), not grading
- LON: shared problem library, de-facto setting standards and establishing baselines
- LON: cross-course cross-institutional dynamic metadata
• Learning Content Management System
• Assessment System
• Multiple Content Representations
• Research on Learning
• Open-Source
The three blocks shown are released at $t=0$ from the positions 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: $M_1 = 1.0 \text{ kg}$, $M_2 = 7.0 \text{ kg}$, $M_3 = 3.0 \text{ kg}$. Calculate the speed of $M_2$ at a time $1.55 \text{ s}$ 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.
**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).

---

**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.

---

Calculate the speed at which the rock is launched.

---

To what height above sea level does the rock rise?

---
Future of Multiple Representations

- Let students pick preferred representation
  - Text
  - Animation
  - Talking head
  - Powerpoint
  - Applets
  - ...

- Have computer keep track of preferences and customize selections and initial offerings
  - ... just like Amazon.com ...
Students receive automatically generated individualized multiple choice exams with their names (and photos).

LON-CAPA machine-grades the bubble sheets.
Exam Support: Re-Takes

A capacitor is completely charged with 650 nC by a voltage source that had 350 V.

1 pt What is its capacitance? (in F)

7. A 1.49 x 10^-9 B 1.86 x 10^-9 C 2.32 x 10^-9
   D 2.90 x 10^-9 E 3.63 x 10^-9 F 4.53 x 10^-9
   G 5.67 x 10^-9 H 7.08 x 10^-9

Now the plates of the charged capacitor are pulled apart with the voltage source still connected.

8. A The charge on the plates increases.
   B The energy stored in the capacitor remains the same.
   C The capacitance increases.
   D The voltage drop between the plates increases.
   E The energy stored in the capacitor increases.
   F The energy stored in the capacitor remains the same.
   G None of the above.

The initial air gap was 8 mm. What is the stored energy if the air gap is now 6 mm? (in J)

9. A 0.00 B 8.53 x 10^-5 C 1.14 x 10^-4
   D 1.30 x 10^-4 E 1.52 x 10^-4 F 3.41 x 10^-4
   G 3.44 x 10^-4 H 4.87 x 10^-4

A capacitor is completely charged with 670 nC by a voltage source that had 350 V.

Problem 6

Due on Tuesday, Feb 22 at 10:00 am

A capacitor is completely charged with 640 nC by a voltage source that has 375 V.

What is its capacitance?

Submit Answer Tries 0/3

Now the plates of the charged capacitor are pulled apart with the voltage source still connected.

- The capacitance increases.
- The voltage drop between the plates increases.
- The energy stored in the capacitor increases.
- The energy stored in the capacitor remains the same.
- None of the above.

Submit Answer Tries 0/2

The initial air gap was 5 mm. What is the stored energy if the air gap is now 10 mm?

Submit Answer Tries 0/3
Exam Support: Re-Takes

Evaluation ➔ Test Bank

Student input screen

Author / instructor output screen

- Overall Assessment Statistical Data
  - Total number of students who have worked on this problem: 766
  - Average number of tries till solved: 1.66
  - Degree of difficulty: (0.40)
  - Degree of discrimination: (0.00)

- Evaluation Data
  - Material presented in clear way: (4.32)
  - Material covered with sufficient depth: (4.55)
  - Material is helpful: (4.45)
  - Material appears to be correct: (4.45)
  - Resource is technically correct: (4.59)

- Evaluation Comments (visible to author and co-authors only)
  - PRIVACY: This was a good problem, but it made you think because you have to make 2 equations with 2 unknowns, but once you got that it was easy to solve.
  - PRIVACY: This was a great problem, and I really like the advice Professor Bauer gave. I understood it perfectly after that.
  - PRIVACY: I thought all the prob's were good in this set. I especially liked this one, though. Including something like Lord of the Rings in a problem gets us science geeks excited. In fact, I did these problems for fun.
  - PRIVACY: I like the theme of the problem. It was not too bad, I just had to think about how to set it up. Once I thought a little, it came along nicely.
  - PRIVACY: Took a while to figure out how to set it up, but afterwards, I felt like it was an easy prob.
- Learning Content Management System
- Assessment System
- Multiple Content Representations
- Research on Learning
- Open-Source
No Significant Difference Phenomenon

This website has been designed to serve as a companion piece to Thomas L. Russell’s book, *The No Significant Difference Phenomenon* (2001, IDECC, fifth edition). Mr. Russell’s book is a fully indexed, comprehensive research bibliography of 355 research reports, summaries and papers that document no significant differences (NSD) in student outcomes between alternate modes of education delivery, with a foreword by Dr. Richard E. Clark. Previous editions of the book were provided electronically; the fifth edition is the first to be made available in print from IDECC (The International Distance Education Certification Center).

The primary purpose of the NSD website is to expand on the offerings from the book by providing access to appropriate studies published or discovered after the release of the book. In addition to studies that document no significant difference (NSD), the website includes studies which do document significant differences (SD) in student outcomes based on the mode of education delivery. Both types of entries may be searched:

- By year, through the left navigation menu;
- Through a simple keyword search, available at the top right of each page; or
- Through an advanced search.

This site is intended to function as an ever-growing repository of comparative media studies in education research. Both no significant differences (NSD) and significant differences (SD) studies are constantly being solicited for inclusion in the website. Please feel free to submit an entry.

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This website is provided as a service of WCET — the Cooperative advancing the effective use of technology in higher education.
Possible Problems with Research on Learning

- If the teaching innovation and the evaluation instrument are not matched, random noise will be measured.
- Humans are not machines
  - Simple input/output models do not work
  - Individuals can give themselves feedback and know when they have learned something
  - Motivated humans will learn, no matter what the tools and methods offered
- The only thing (almost) universally agreed upon:
  - Learning needs to be fun
  - More time-on-task is beneficial
Students spend more time on task AND rate LON-CAPA as very helpful!

Total number of students: 144
LON-CAPA - Research on Learning

Across a number of studies:

Improved exam performance

Improved course performance

Improved performance especially of female students
When do Students Work?

- Homework due at midnight
- 770 students in class

Thursday, Oct. 8
Network Traffic During the Week

Week from Thursday, Oct 1, to Oct 8

Homework is due on Thursdays at midnight

W. Bauer, October 2006, UC Berkeley
Virtual University Physics

- Phy231c and Phy232c at MSU
- No lectures, no textbook
- All materials in lecture Online
- Asynchronous interaction with students via e-mail (~1000/semester)
- Synchronous interaction via chat-room and (physical) help-room
- Instructor spends more one-on-one time with students
  - No lecture, no homework grading, minimal grade database maintenance
  - Time savings result in more office hours and student contact
Enrollment

- Fall 97: 32
- Spring 00: 293
- Enrollment capped at 300 since then
- Since 99/00: AP Physics
  - Contract with Apex Learning (P. Allen)
  - ~200 high school students in first class
  - Exponential growth
Do they learn better?

- Comparison study in Fall 1998: Taught lecture based PHY231 and compared to PHY231c
- Same homework assignments, same exams, same grading system
- Virtual university students scored slightly higher on all three exams and on FCI baseline test, and obtained slightly higher final grades (2.93 vs. 2.87) on average
- Statistically significant effect!
- One explanation: putting materials on www forces the students to engage in more active learning
- Another: VU students are self-selected group
Virtual Physics Laboratory Exercises

What is essential about lab exercises?

• Act of taking data
• Processing of data
• Error estimate
• Lab report

Not essential:

• Physical touching of apparatus
• Possibility to hurt oneself

Physics Java Labs

Please complete all of these labs before the end reports (as email attachments) back to the instructor.

Before you start your lab report, it might be useful:

Lab 1: Determination of g
Lab 2: Collisions and Conservation L
Lab 3: Pendulum
Lab 4: Phase Transitions
Lab 5: Archimedes’ Experiment
Lab 6: Fluid Flow
Lab 7: Photo Effect
Lab 8: Nuclear Decay

One of the premier goals of each laboratory: how to deal with measurements uncertain on how to calculate your best values and couple usefull links:

• Mean values and error estimates
• Error propagation
• Calculator for mean values and statistics
Virtual Lab: Determine $g$
OUTLINE

- Learning Content Management System
- Assessment System
- Multiple Content Representations
- Research on Learning
- Open-Source
LON-CAPA

- Open-source free software
- No license fees
- GNU General Public License
- Can be modified, extended, improved, adapted ...
- Runs on Linux, no license fees for operating system
- Developed by educators for educators
OPEN SOURCE

- Code contributions by
  - Michigan State University
  - Florida State University
  - Ohio University
  - Simon Fraser University Vancouver
  - Hebrew University Jerusalem
  - UNICAMP São Paulo
Internationalization

- Rewrote most screen output such that it can be localized into other languages.
Currently used at 44 high schools, 3 middle schools, 4 community colleges, 6 content development projects, 6 publishing companies, and 37 universities in the USA.
What is TheDump?

Short for Teachers Helping Everyone Develop User Materials and Problems, TheDump is a collection of K-12 level resources on the LON-CAPA network. Easily imported into courses, these sequences make it easy to add tested and well-written problems from several sources into a course. Along with university coordinators from Michigan State University and Florida State University, TheDump is currently run and headed by K-12 teachers from around the Mid-Michigan area.

Current Content

As of May 2006, TheDump contains sequences with over 500 resources, written and used around the world. While the bulk of the problems are currently in the physics discipline, efforts are underway to expand and build a library of mathematics.

Current subjects and disciplines in the system (but are not limited to):

- Physics
- Chemistry
- Biology
- Earth Sciences
- Calculus (in progress)
- Algebra I (in progress)
- More to come...
LON-CAPA Installations

**Multiple:** USA, Canada, Brazil, Japan, Germany

**Single:** Chile, India, Italy, Israel, Zimbabwe
Resource Sharing

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</table>

**Table 2:** Top dozen learning content providers (columns) and users (rows). Universities are labeled "U," community colleges "CC," high schools "HS," middle schools "MS," projects "PR," and publishing companies "PU." The first row shows the total number of resources which the domain is making available to the pool, the second row the number of resources actually being used, and the third row the number of resources which are used at a domain other than its own. The first column shows the total number of resources a domain is using for its courses, and the remaining cells show how many resources the domain in the row is using that originated in the domain in the column. Italics indicate an institution using its own resources.
Welcome

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September 26, 2006
Michigan State University Open Source Project Fuels Bottom-up Teaching Innovation

The LearningOnline Network with Computer-Assisted Personalized Approach, or LON-CAPA, is an innovative Michigan State University Web-based service allowing educators to easily create and share course material across a range of subjects. Full story

Source: Michigan State University

September 25, 2006
Using Synthetic DNA, Cornell Researchers Fashion Low-cost, Biodegradable Hydrogels for Drug Delivery and Tissue Engineering

Using synthetic DNA formed into crosses, Y’s and T’s, Cornell researchers have created biocompatible, biodegradable, inexpensive hydrogels that can be easily formed into any desired shape for biomedical applications. Full story

Source: Cornell
Collaboration
Closing Thoughts

- Initially developed at Michigan State University
- Funding received from
  - NSF ITR grant
  - Mellon Foundation
  - Sloan Foundation
  - Howard Hughes Medical Institute
- April 2006: LON-CAPA consortium formed
  - Founding members: MSU, Illinois, more in the process of joining
  - Open invitation to join us