Developing the open source on-line homework system WeBWorK within academia

AMS Committee on Education
October 14, 2016

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WeBWorK | Meliora Mathematica
University of Rochester

To

AMS Committe on Education

Thank you!

Mike Gage
Arnie Pizer

First: What is WeBWorK?

- WeBWorK is an open source web-based homework checker. (Similar to the commercial WebAssign product)
- WeBWorK was originally designed at the University of Rochester and is now actively supported by math and science faculty throughout the US.
- Supported by Math Association of America (MAA) and the NSF.

Main points about WeBWorK

1. WeBWorK was designed as an experimental platform and has successfully evolved over 20 years, adding new features but keeping a core of continuity. It is still easy to bolt new features on to WeBWorK — it may not always be elegant but it usually works.

2. WeBWorK has a broad installed base of users (over 750 institutions) and has moved well beyond the "early adopters". New features in WeBWorK are likely to have significant impact in mathematics classes within a short period of time.

3. The Open Problem Library (OPL), a curated collection of math homework problems contributed by many faculty, is an important content resource containing more than 30K items.

4. The open experimental architecture allows the components of WeBWorK to interoperate separately with other software. Connects with Moodle, Canvas, Blackboard, Mathbook XML…

Simple interval example

Entered	Answer Preview
(-3,7)	$\left(-3, \frac{35}{5}\right)$

The answer above is correct.

(1 pt)

The interval described in set notation by the inequality $|5x - 10| < 25$ has interval notation:

(-3,35/5)

Sample responses to incorrect answers

Entered	Answer Preview	Messages
(-3,7]	$(-3, 7]$	The type of interval is incorrect

Entered	Answer Preview	Messages
(-3,,35/5)		Missing operand before ','

Goal:

WeBWorK | Meliora Mathematica University of Rochester

Make homework more effective and efficient.

- Homework: Learning opportunity.
  Quizzes: Assessment
- It increases the effectiveness of traditional homework as a learning tool by:
  - Providing students with **immediate feedback** on the validity of their answers and giving students the opportunity to correct mistakes while they are still thinking about the problem. As one student said, *"I can fix my mistakes while [the] problem is fresh in my mind."*
  - Providing students with **individualized versions** of problems which means that instructors can encourage students to work together; yet each student must develop an answer to his or her own version of the problem.

Goal:

WeBWorK | Meliora Mathematica University of Rochester

- It increases the efficiency of traditional homework by:
  - Providing **automatic grading** of assignments.
  - Providing information on the performance of individual students and the course (or section or recitation) as a whole.
- Key Features:
  - Using WeBWorK, instructors can ask most questions typically found in mathematics and other scientific textbooks as well as more advanced interactive questions.
  - Students **persist** with WeBWorK. At Rochester we find almost all students complete each homework set until most problems are correct.

Philosophy

- WeBWorK offers maximum extensibility and flexibility
- **Ask the questions you *should*, not just the questions you can!**
- **More than 30,000 questions contributed by mathematicians to the problem library.**

Developed by mathematicians for mathematicians

from: *Promoting Work on Education in Mathematics Departments*, William G. McCallum, AMS Notices, September 2003

Bill:

… I asked one of the designers of the system, Michael Gage, whether he thought the fact that the system was designed by mathematicians made it particularly different from other such systems. Here is his reply:

The strong focus on being able to adapt the system to the problems you want to ask, rather than the problems you can ask, stems from a research/educator's point of view more than a math education researcher's (which is legitimately somewhat different) or a programmer's.

I doubt that a group from instructional technology would have designed a system with the same set of strengths (and weaknesses).

— Mike Gage

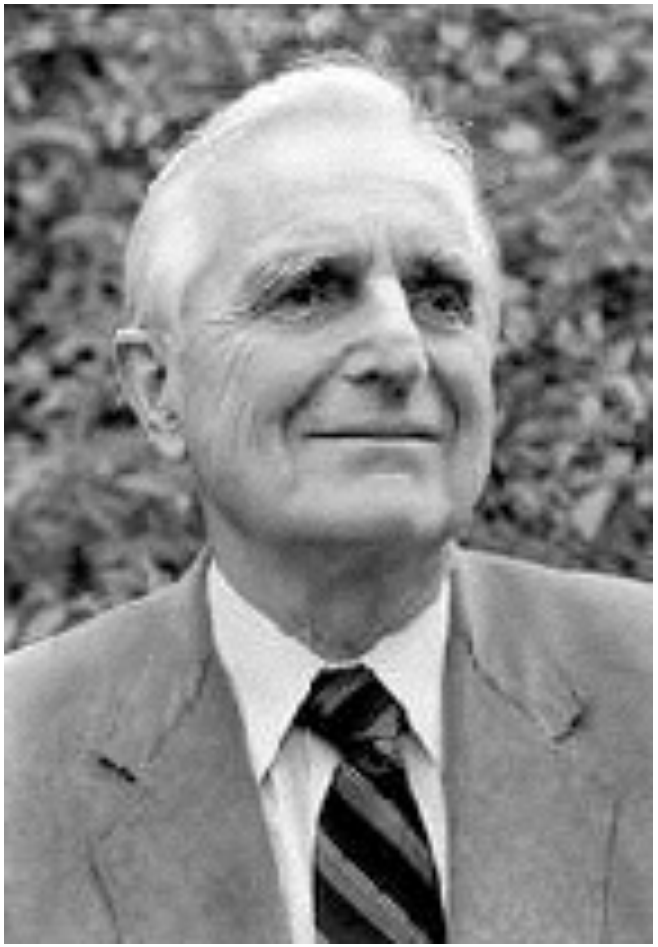
Talk outline

- Overview of WeBWorK history
- WeBWorK early history
- Technical interlude
- WeBWorK growth spurt, dissemination and “code camps”.
- Summary
- What is next?

1995

NeXT computer

- Frank Wolfs, UR physics department
- CAPA homework system (developed at Michigan State U.)
- 24 students with direct dial-in to NExT computer
- Works for physics word problems but only so-so for math
- Needs to be better — perhaps use the new fangled World Wide Web?



Personal aside:

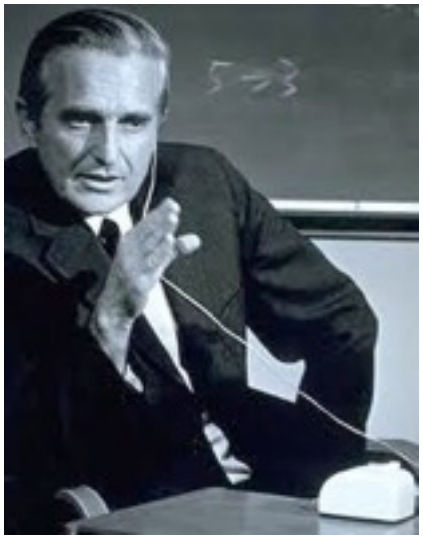
Doug Engelbart

Stanford Research Institute

"The important use of computers is for communication not for number crunching"

-- 1972

The mother of all demos 1968



1995

Use **Perl**, the **World Wide Web,** the **Apache** server and the web browser **Netscape** to replace the dial-in connection and the limited authoring language.

NETSCAPE®

Marc Andreesen

Jim Clark

November 1995

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Rochester Renaissance Plan for The College

November 16, 1995

Tweet Like 0 G+1 0

On November 16, 1995, University of Rochester President Thomas H. Jackson announced a sweeping "Rochester Renaissance Plan" for the College, which includes the arts and sciences and School of Engineering and Applied Sciences.

Grading every homework assignment of every student became a high priority!

1996

- Fortunately: "On March 29, 1996, the University of Rochester issued the following press release about the reversal of its move to downsize its mathematics department." —AMS notices, June, 1996 — Allyn Jackson
- Rapid development of the homework application over the summer by Arnie, Mike and undergraduate interns.
- Arnie Pizer coins name WeBWorK (Web + Homework)
- September 1996, Arnie Pizer teaches first class "MTH140a Calculus with Foundations" using WeBWorK.

November, 1997

- AMS Notices:
  — Allyn Jackson

Whatever Happened to Rochester? Two Years Later, Mathematics Is Getting Accolades

Improvements in Teaching

"The mathematics department started making improvements in the area that had drawn the most complaints: lower-level teaching. One of the most visible manifestations is WeBWorK, an Internet tool developed by Michael Gage and Arnold Pizer. (Ironically, WeBWorK was under development even before the crisis broke at Rochester.)"

1999

- Several dozen other universities are using WeBWorK
- Spread by word of mouth through the mathematics research community and through department chairs through the efforts of Doug Ravenel, chair of the UR math department.
- Arnie Pizer and Mike Gage receive ICTCM award

Award for Excellence and Innovation with the Use of Technology in Collegiate Mathematics

1999 San Francisco, ICTCM-12[8]

- To: **Michael E. Gage (et al.)**, University of Rochester and **Arnold K. Pizer**, University of Rochester
- For: ***WeBWork***[9]
- To: **Christopher Weaver**, New Mexico State University
- For: ***Mathematics Accessible to Visually Impaired Students***

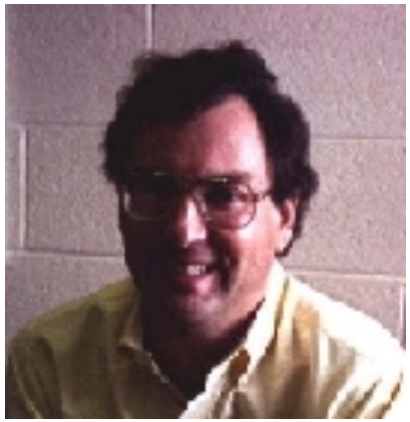
International Conference on Technology in Collegiate Mathematics — ICTCM

1999 — 2002

1999 First NSF grant

Michael Gage
Arnold Pizer
Vicki Roth

Co-PIs



Mike Gage Arnie Pizer Vicki Roth

1999 — 2002

2002 Presentation at ICTM in Crete:

Michael Gage
Vicki Roth

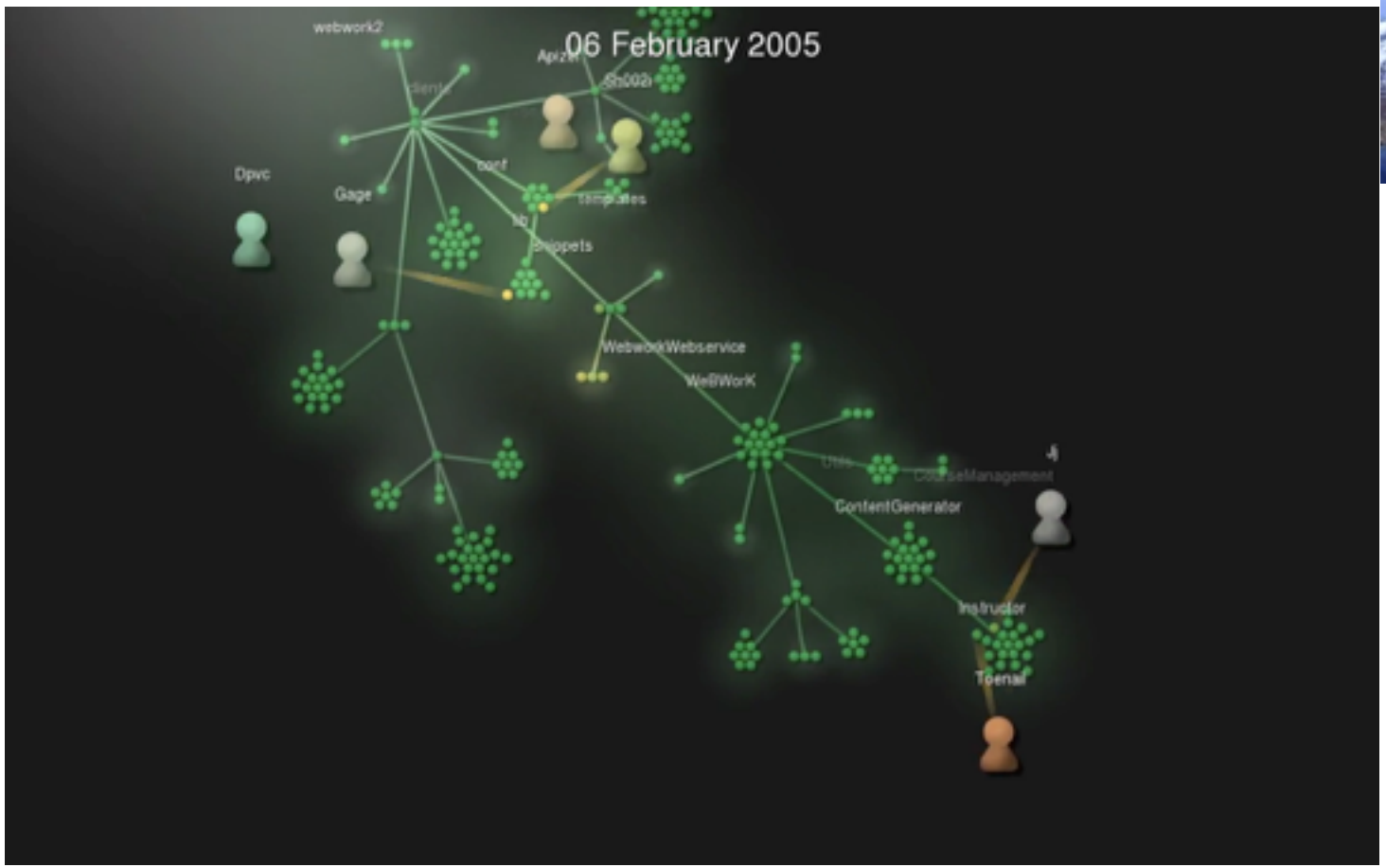
SECOND INTERNATIONAL CONFERENCE ON THE TEACHING OF MATHEMATICS (at the undergraduate level)

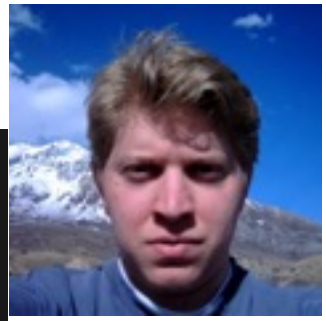
1 - 6 July 2002
Hersonissos, Crete
GREECE

Developing WeBWorK2: 2002 -- 2012

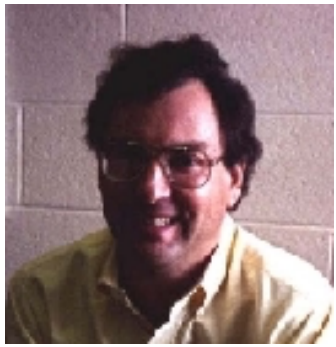
Sam Hathaway

Davide Cervone





Rob Van Dam



Arnie Pizer

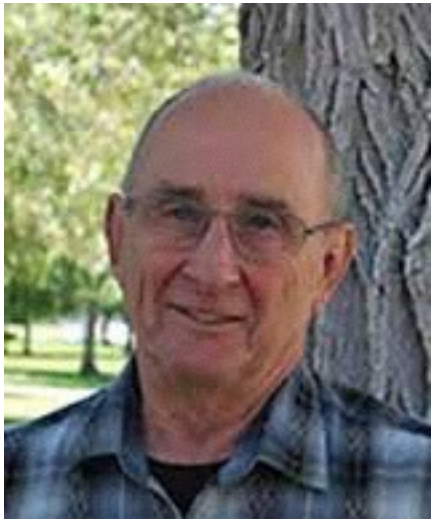
Search for: youtube, webwork, gource Gource stands for "Graphical source"

Contributors: Gage, Sam Hathaway, Dennis Lamb, Pizer, and others.

2002 - 2009

2004: MSRI sponsors a development workshop

Gage, Pizer, Davide Cervone,
Gavin LaRose, John Jones, Jeff Holt



Hugo Rossi, MSRI and U. of Utah

MathObjects, jsMath, WW2 instructor framework

National Problem Library and LibraryBrowser ideas are born
(John Jones and Jeff Holt lead developers)

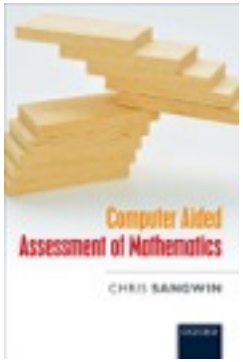
2007 — AIM workshop

August 2007 - American Institute of Mathematics in Palo Alto, CA sponsors workshop on WeBWorK development and outreach

WeBWorK Workshop at AIM
August 2007
and
100's of instructors writing questions
(more than 12,000 collected in the national library)

Brief technical interlude

- We knew we would make mistakes in the WeBWorK design so we built a very open architecture with plugins and callbacks.



- *"WeBWorK was built on freely available web technology, and the software is claimed to be used by more than 240 colleges and universities. Combining technologies in this way, rather than writing dedicated desktop software, was rather innovative at the time. The module construction and extensibility, both of the underlying mathematical software and front end,* ***have enabled WeBWorK to evolve more or less continuously for the last fifteen years.****"*

Computer Aided Assessment of Mathematics,
—— Chris Sangwin, 2012

Brief technical interlude

WeBWorK2

Front End
WeBWorK2

Math Typesetting
~~tth~~
~~Latex2HTML~~
dvipng
~~jsMath~~
MathJax

Database

~~GDBM~~

MySQL

Back End
PG renderer

AnsEvaluation

~~Perl eval()~~
~~AlgParser~~
MathObjects

Davide Cervone

WeBWorK2/PG remarks

- Features on the WeBWorK2/LMS side and features on the PG/QuestionEngine side develop somewhat independently.
- We've been using a web service to expose the PG side so that it can be plugged in to other LMS in various ways.
  - Moodle, Canvas, Blackboard, Mathbook XML, webpages.
- I expect someday that the WeBWorK2 LMS will be superseded but for now it provides useful and familiar functionality to the people using it.
- The PG side is harder to replace without rewriting the 30K problems in the OPL

PG problem assumptions

- The problem template is a string.
- The student answer is a string.
- The language "PG" (ProblemGenerator? PrettyGood?) consists of plugin subroutines (macros) that process the template to produce HTML or TeX output. (Hardcopy has been important from the beginning.)
- The answer evaluators are subroutines which take the student string, process it, and return "right" or "wrong" (and helpful error messages). Because the underlying language is (usually) perl you can build an answer checker for any response that you can analyze with an algorithm.

2009 - present

- Growth spurt
- Dissemination
- Code camps

2009 — Partnership with MAA

5 year NSF dissemination grant

http://webwork.maa.org

2009-2014 Dissemination

The plan worked well:

- 2009 — 150 institutions
- 2010 — MAA hosting service goes live
- 2011 — 490 institutions
- May 2013 — 670 institutions, 220 websites serving WW, 450 hosted at MAA website, more than 64 high schools
- June 2014 — 768 institutions,
- Oct 13, 2016 — 1120 institutions listed on MAA website
  - 770 institutions active during fall 2015 and spring 2016

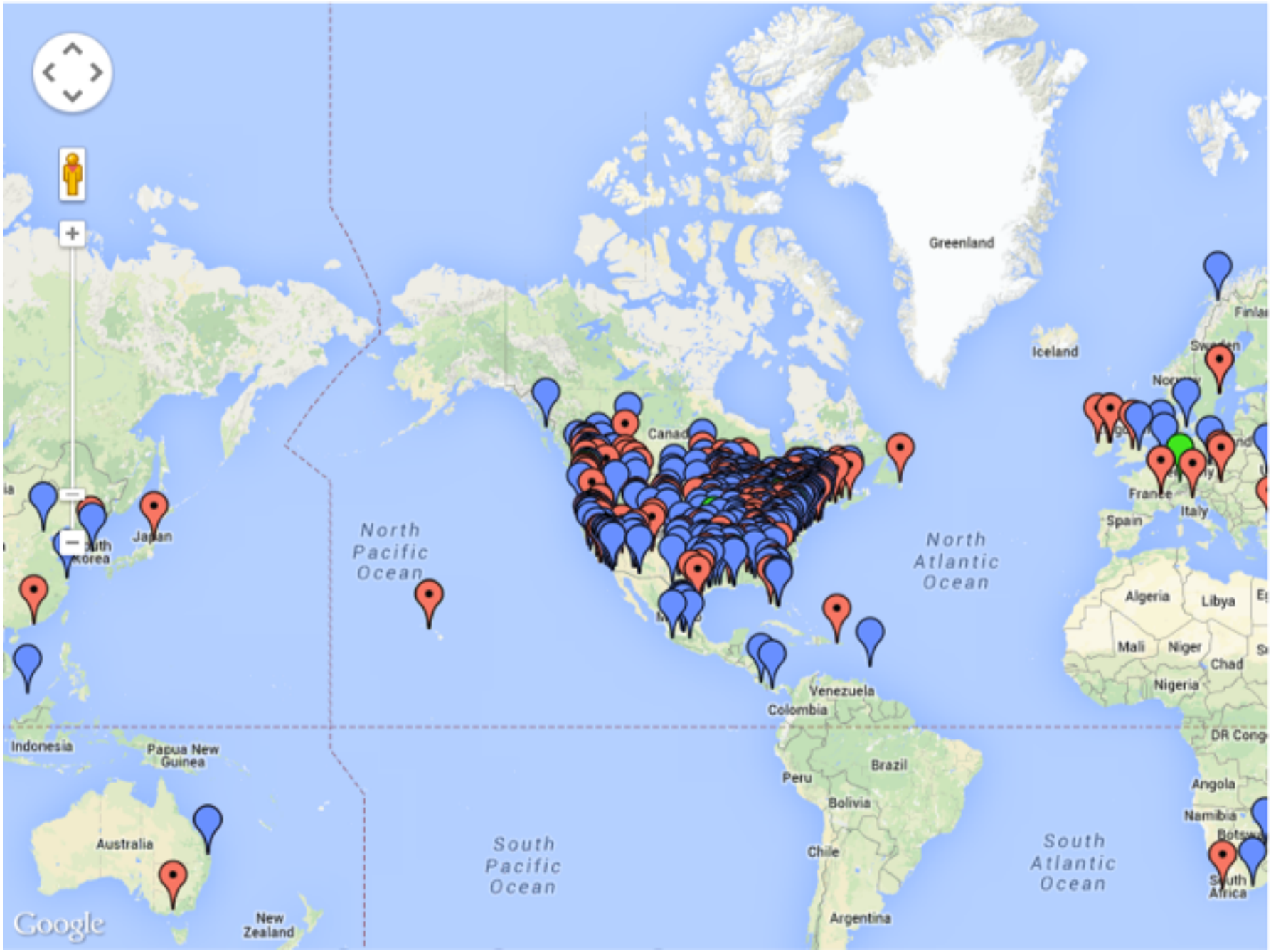
WeBWorK sites -- 2011

2015

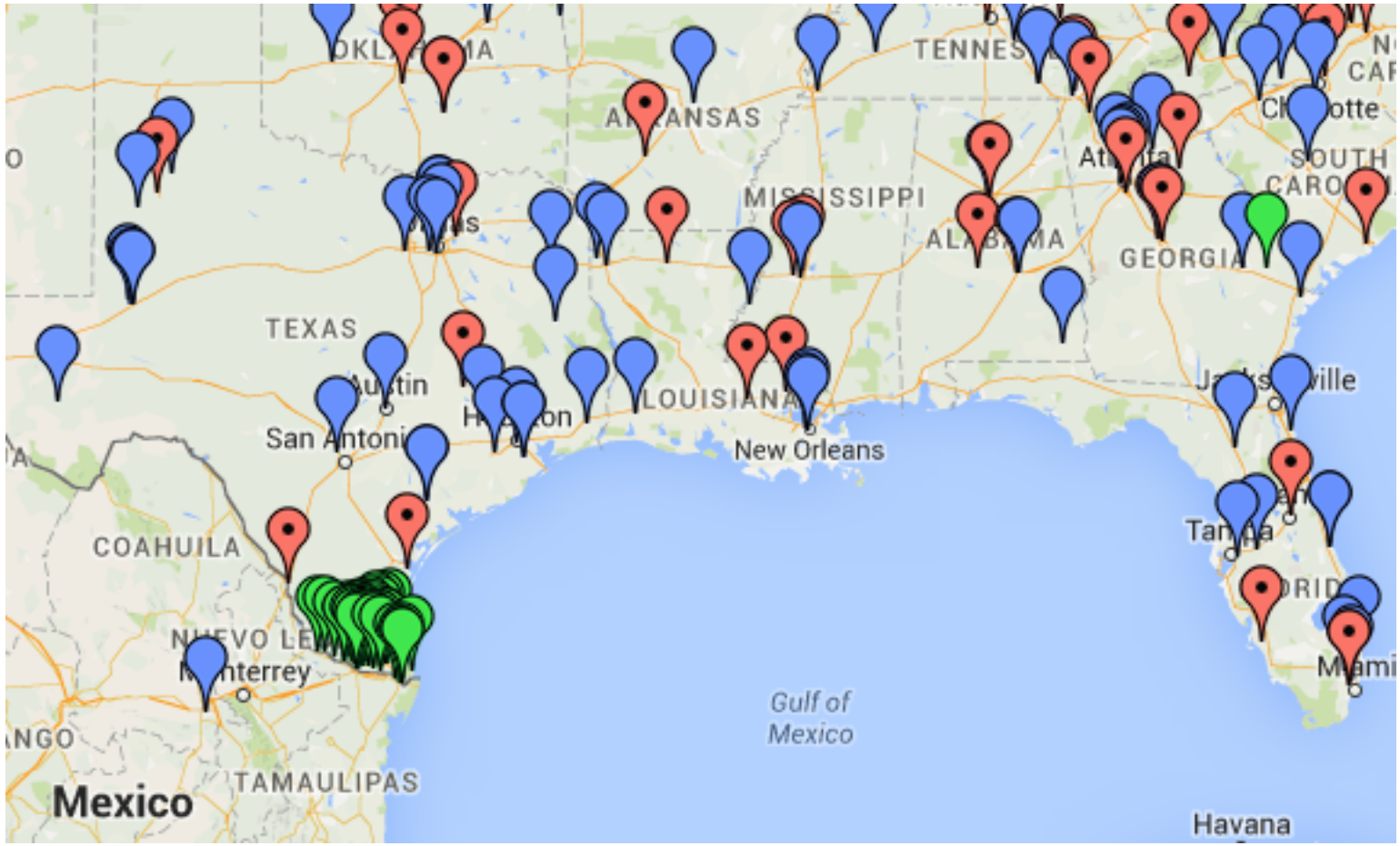

BC
SK
MB
ON
QC
NL
MT
ID
CO
NM
Gulf of Mexico
Cuba
Guatemala
Caribbean Sea
Venezuela
Guyana

WeBWorK Sites — 2014

760+ institutions



2015 — hosted high schools



The **University of Texas, Pan America** hosts a WeBWorK site serving math homework to dozens of regional high schools.

New needs (~2011)

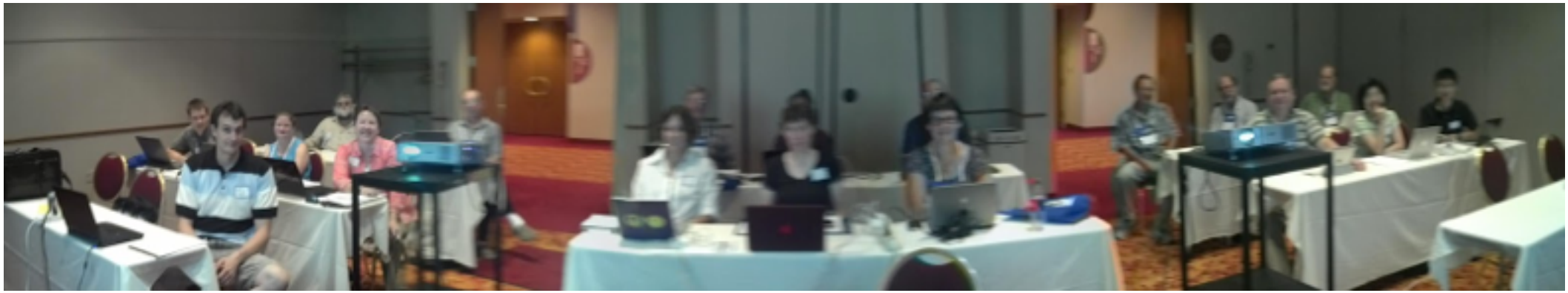
- With a larger user base more of our instructors were not self-sufficient experimentalists. Everyone wanted an easier instructor interface.
- The standard Web1.0 interface which had remained fairly static between 2000 and 2006 began to change rapidly thereafter — the influence of Google docs and gmail apps leading the way toward Web2.0.
- The targeting mobile devices became more important.
- Academic software development is never done. :-)

The fix: Code camps 2012—

- Code camps are short, intense development workshops.
- We got the idea from attending SageDays code camps (Sage is an open source Mathematica).
- and from POSSE "Professor's open source summer experience".
- From 2005 through 2012 we had produced a new WeBWorK release about every 1.5 years
- From 2012 to 2014 we held about 4 code camps per year and moved from WeBWorK version 2.5 to 2.9 with approximately 2 releases a year.
- Since then we've had fewer code camps but have still progressed to release 2.12.

WW code camps

- WW::Winona -- August 2012



Stealing the sageday ideas from Sage we have are now holding WW development camps regularly:

- WW::Rochester -- June 2012

- WW::Fitchburg -- October 2012

WW code camps

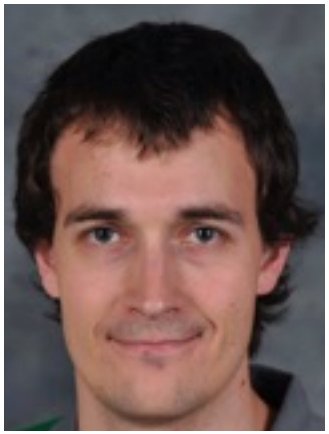
- WW::Raleigh -- March 2013
- WW::AnnArbor -- May 2013 (modelCourses & database)
- WW::Vancouver -- June 2013 (UI and database)
- WW:: Rochester::2013 — October 2013
- WW::Asheville — May 2014
- WW::Portland —August 2014 (accessibility)
- Read about the code camps on our blogs: http://webwork.maa.org/planet

More key developers

The consulting sessions and code camps were key to getting new people involved. Among them

Peter Staab

Geoff Goehle



Paul Pearson

John Travis

Jason Aubrey

Gavin Larose

John Jones

Jeff Holt

Alex Jordan

The impact has been substantial

- Most educational innovations sponsored by the NSF affect only a few schools. Sometimes only one department.
- The fact that 770 schools used WeBWorK last semester alone means that every new idea, innovation or improvement embedded in WeBWorK will spread to these schools within a year.
- We have also built a coalition of a few dozen programmers contributing new features.
- and hundreds of faculty contributing questions, editing them and categorizing them.
- The OpenProblemLibrary (OPL) editorial workshops deserve their own story! (invite John Jones and Jeff Holt)
- Over time WeBWorK will produce the best possible collection of mathematics teaching problems. Commercial firms don't have the resources or the drive to compete with teaching faculty pooling their best ideas over years.

Unanswered questions

- Is WeBWorK development sustainable over the very long term?
  - It's harder to get grant funding for established long term projects.
  - As the number of code camps has dwindled this last year and a half I've already noticed less cohesion and focus in our development. Our "webwork3" AJAX based instructor interface needs much work to be ready for general release.
  - More importantly the incorporation of new developers into the project is slowing down.
  - What is the proper role of open source development for academic materials? How should it be supported?
  - In the USA a common answer is commercialization and entrepreneurship — but I'm personally not convinced that's the best answer.

Unanswered question:

- How should open source development for academic materials be supported?
- All of the following open source applications interoperate.
  - Sage
  - Geogebra
  - WeBWorK
  - STACK
  - TeX/LaTeX, MathJax
  - OpenStax textbooks (Open Educational Resources OER)
  - Moodle
  - Mathbook XML
  - HTML demo….
  - …..

Summary

- Software will become an increasingly important part of education as well as research. It should be open source software.
- Software created by mathematicians for mathematicians is a good idea.
- "Ask what you should, not just what you can" is important for good mathematics learning and for good research into how students learn mathematics.
- So far "Code camps" have seemed to be the most efficient way to keep a distributed academic open source project moving forward in a timely manner.

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Thank you

- What is the proper role of open source development for academic materials?
- How is it to be supported?

Reference links

References

- https://hosted2.webwork.rochester.edu/gage/2016coe
- http://webwork.maa.org/wiki (main wiki)
- http://webwork.maa.org/planet (blog posts)
- WeBWorK forum — linked to from wiki
  - register on wiki to obtain posting rights on forum
- https://hosted2.webwork.rochester.edu/webwork2/
  — UR10x WeBWorKdemo courses
  — use login/password: profa/profa
- https://devel3.webwork.rochester.edu/moodle/
  — Linear algebra 2009 — use login/password: visitor/visitor
  — WW quiz and assignment plugin demo
- https://github.com/openwebwork
  — webwork2, pg, webwork-open-problem-library

New or under used features:

- A quick tour of features that are under used.

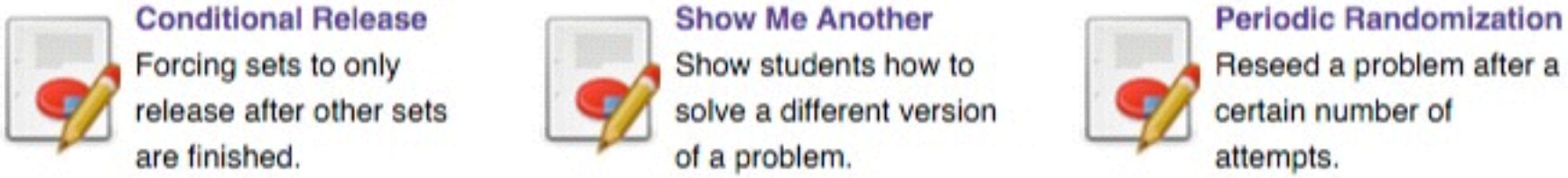
Did you know that….?

webwork.maa.org/wiki

Instructors

- You can "**conditionally release**" a problem. It can't be attempted until one or more other problems have been done.
- "**Show me another**" — Show students how to solve a different version of a problem.
- "**Periodic Randomization**" —- Reseed a problem after a certain number of attempts. (rel 2.12)

These options need to be turned on in the "Course Configuration" page.



Did you know that….?

webwork.maa.org/wiki

Blogs

- You can **link** WeBWorK to Blackboard, Canvas, Moodle and any other LearningManagementSystem (LMS) supporting LTI. The student is signed in automatically to WW (SSO) and the homework grade is passed back.
- You don't have to enter students into WeBWorK — Blackboard, Canvas or Moodle takes care of it for you.

Moodle demonstrations

Did you know that….?

webwork.maa.org/wiki

Instructors

- You can write new problems in simplified mark down language PGML (PG markdown). For most people this is simpler than writing directly in Perl.

Intro To Writing Your Own Homework Problems Using PGML

A Gentle Introduction

Did you know that….?

webwork.maa.org/wiki

Blogs

- You can print **hardcopy** in a single column format, as well as the traditional double column format. (rel 2.12 —Goehle)
- You can develop your own themes.
- You could **print out exams or worksheets** from collections of WeBWorK problems.

Did you know that….?

webwork.maa.org/wiki

Instructors

- You can create a "**reduced scoring period**" — Late homework is accepted the maximum score is reduced — Pizer, et. al
- You can enable "**Achievements**" — gamefication of WeBWorK homework. —Goehle
- You can add an **essay question** to any problem.
- Adaptive homework: **Just-in-time** problems can add supplemental work for students having trouble.
- These options need to be turned on in the "Course Configuration" page.

Goeff Goehle

Did you know that….?

- You can embed WeBWorK problems anywhere — even in an HTML page. The problems are live, but are not graded.
- Using this technology one can embed live examples into textbooks.

HTML demonstrations

- We are exploring this with MathBook XML
  - Rob Beezer at University of Puget Sound
    MathBook XML
  - Alex Jordan at Portland Community College
    WeBWorK in MathBook XML
- And with OpenStax (Rice University)
  OpenStax Calculus

Conclusions/questions

Some larger questions

- What is the role of OER in and open source software development in academia?
- Lower cost?
- Encourages more instructor engagement?
- Can it be sustained?