WeBWorK | Meliora Mathematica
University of Rochester

The WeBWorK on-line homework system and its academic community

E-Assessment in Mathematical Sciences

September 13-14, 2016
Newcastle University
Newcastle upon Tyne, United Kingdom

Michael E. Gage

University of Rochester

Encourage communication among open source math education tool projects

- STACK

- Numbas

- Moodle

- GeoGebra

- SageMath …

- WeBWorK

- Mathbook XML

- MyOpenMath

- CaluMath

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…

Philosophy:

- WeBWorK focuses on extensibility and flexibility in expressing math content and analyzing student answers.

- **Ask the questions you *should*, not just the questions you can!**

- **More than 30,000 questions contributed by mathematicians to the problem library.**

Talk outline

- show case some WeBWorK math questions

- review some history — the "WeBWorK story"

  - code camps and sustaining open source development

- OpenProblemLibrary and LibraryBrowser

- Interoperability

  - with Moodle, (also Canvas, D2L/Brightspace, etc.)

  - with Sage, Geogebra, R — these plug in to webwork

  - HTML pages, 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 ','

More examples

- Student view — 2nd semester calculus course (<u>hosted2</u>)

- WeBWorK problems embedded in an HTML page. (<u>hosted2</u>)

Brief history of WW

- Summer 1996: CGI version of WeBWorK1 assembled from Perl, Apache, CGI and the Netscape browser.

- Fall 1996 — First classes taught with WeBWorK1

- 1999 — WW1 wins ICTCM award, NSF funding begins (Gage, Pizer and Roth principle investigators)

- 2004 — MSRI workshop — WW2 interface debuts, Davide Cervone adds jsMath (precursor to MathJax) and MathObjects

- 2007 — Workshop at American Institute of Math (AIM)

- 2009 — NSF dissemination grant in partnership with MAA (about 150 institutions using WW)

- 2016 — Gage and Pizer win AMS Committee on Education "Impact" award for WeBWorK

1995

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

Marc Andreesen

Jim Clark

by 1999

- Several dozen other research 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

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
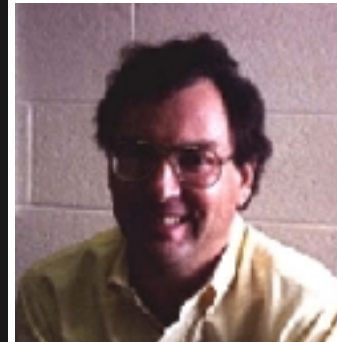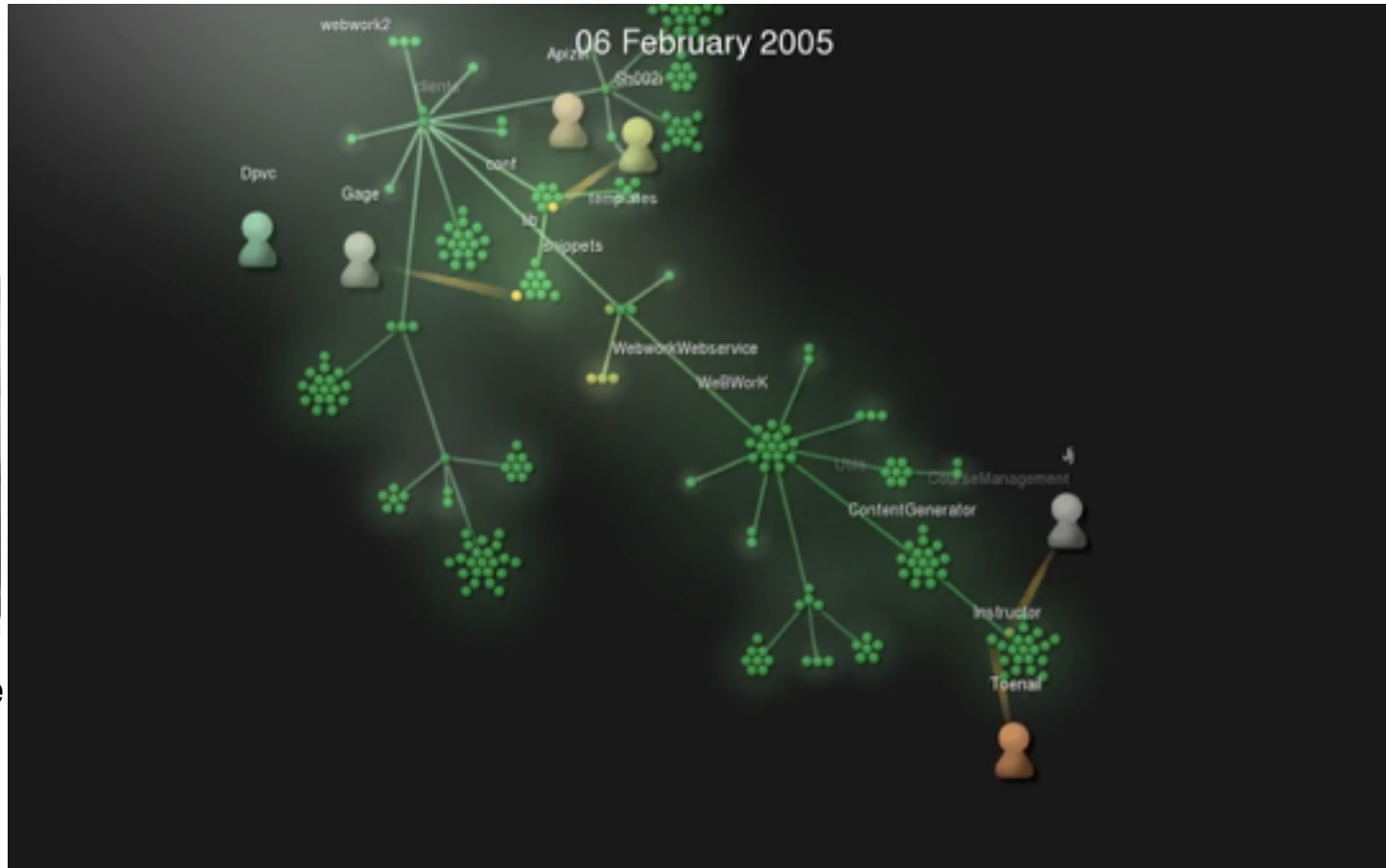GREECE

Developing WeBWorK2:
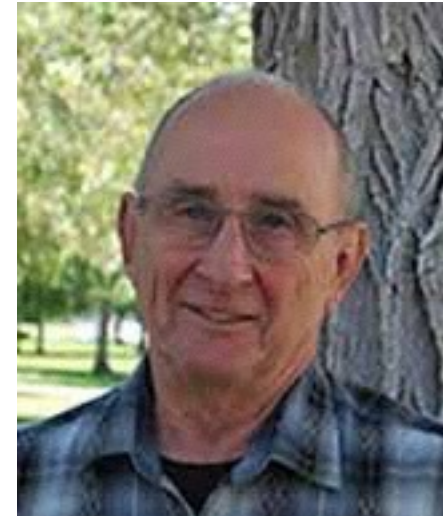## 2002 -- 2012

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
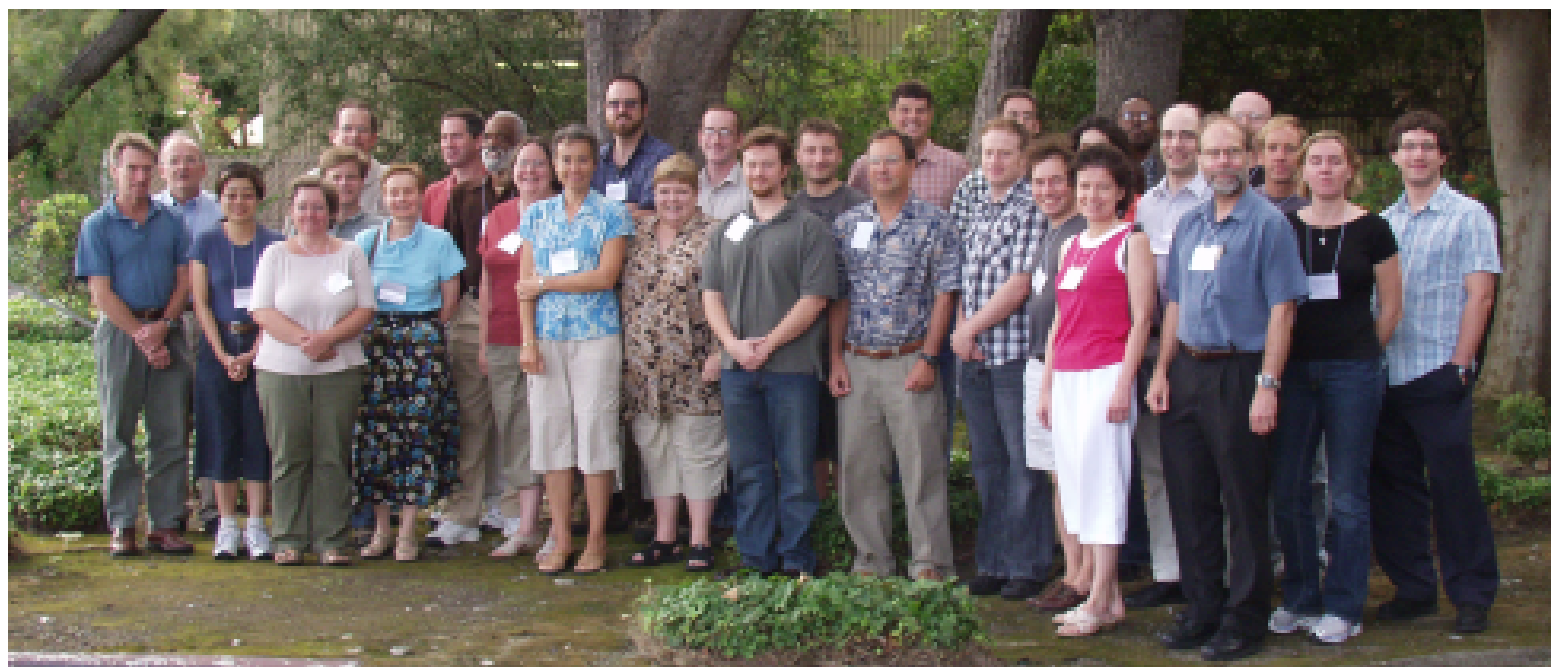

Hugo Rossi, MSRI and U. of Utah

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
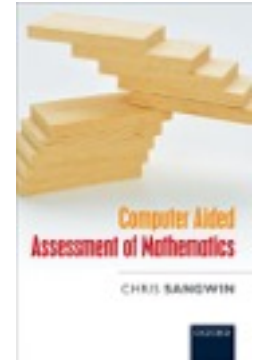

WeBWorK Workshop at AIM
August 2007
and
100's of instructors writing questions
(more than 12,000 collected in the national library)

Brief technical interlude

- We knew we would make mistakes in the WeBWorK design so we built a very open architecture with plugins and callbacks.
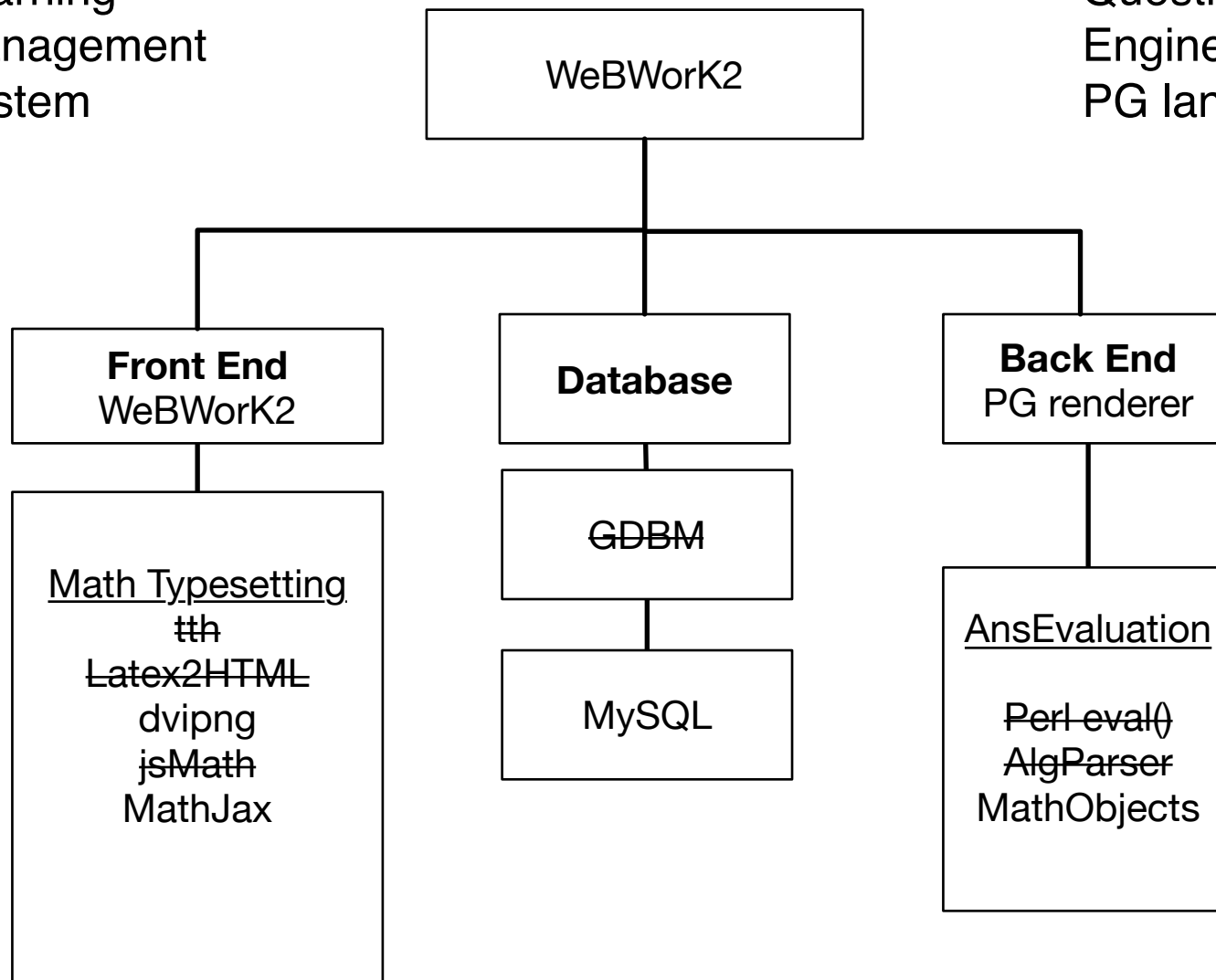
- *"WeBWorK was built on freely available web technology, and the software is claimed to be used by more than 240 colleges and universities. Combining technologies in this way, rather than writing dedicated desktop software, was rather innovative at the time. The module construction and extensibility, 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

Learning
Management
System

Question
Engine and
PG language

```
                              WeBWorK2

     Front End              Database              Back End
     WeBWorK2                                     PG renderer

  Math Typesetting           GDBM               AnsEvaluation
      tth
    Latex2HTML                                    Perl eval()
      dvipng                  MySQL               AlgParser
      jsMath                                      MathObjects
      MathJax
```

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 — Partnership with MAA

5 year NSF
dissemination grant

http://webwork.maa.org

2009-2014 Dissemination

The plan worked well:

- 2009 — 150 institutions. Began outreach workshops

- 2010 — MAA hosting service goes live

- 2011 — 490 institutions (the original goal of the grant was 450!)

- 2012 — code camps replace outreach workshops

- May 2013 — 670 institutions, 220 websites serving WW, 450 hosted at MAA website, more than 64 high schools

- June 2014 — 768 institutions listed ,

- September 2016 — 1114 institutions, (770+ active during 2015-2016 academic year)

2011 http://webwork.maa.org/wiki/WeBWorK_Sites

WeBWorK Sites — 2014

760+ institutions

2015 — hosted high schools webwork.maa.org/wiki/ WeBWorK_Sites

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.   :-)

Our fix: Code camps 2012—

- Code camps are short, intense development workshops. — basically HackFests

- 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

- Between 2012 and 2014 we averaged 4 code camps per year and moved from WeBWorK version 2.5 to 2.12 with approximately 2 releases a year.

WW code camps

- WW::Winona -- August 2012
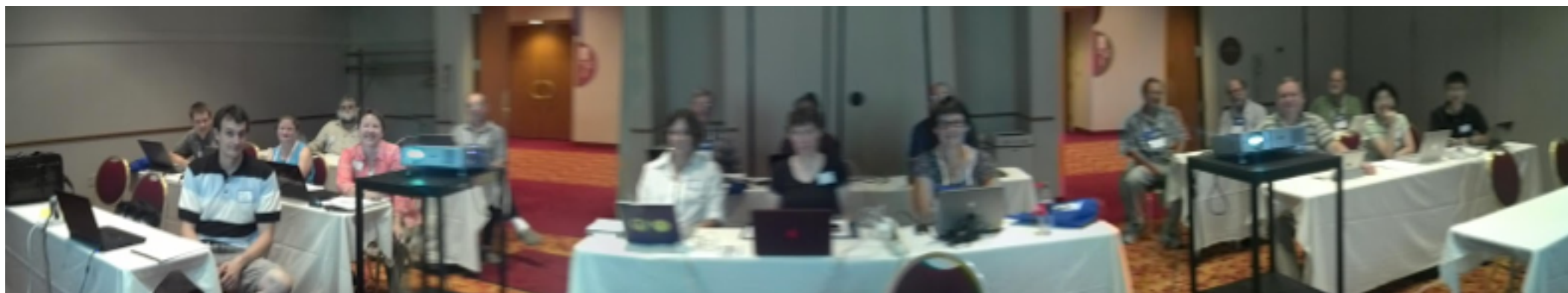
Stealing the sageday ideas from Sage we have are now holding WW development camps regularly:

- 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:
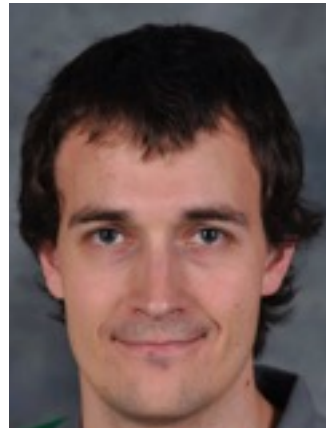 http://webwork.maa.org/planet

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

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 a smaller group that can integrate these into the existing code.

- and hundreds of faculty contributing questions, editing them and categorizing them in the OpenProblemLibrary. More about the OpenProblemLibrary in a minute.
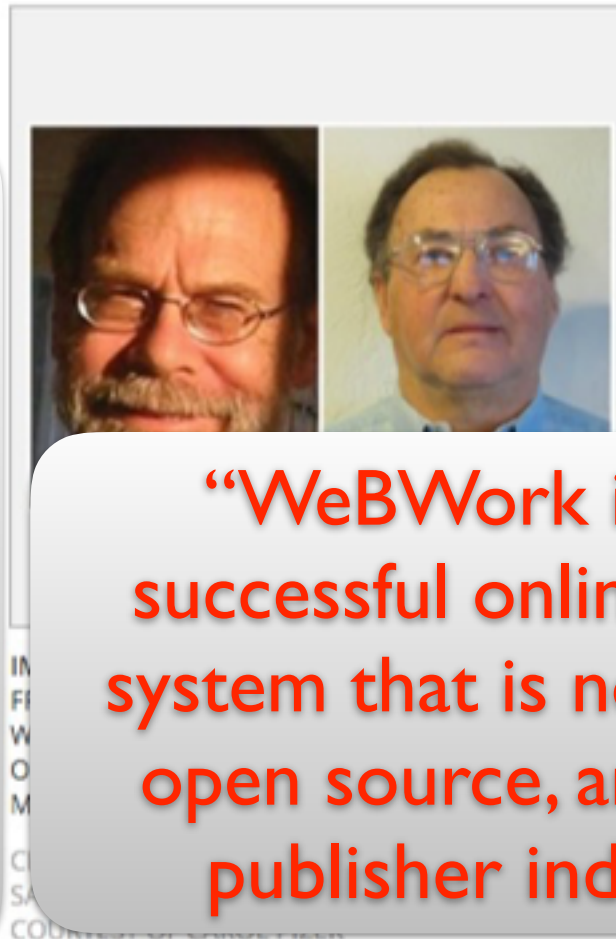
Michael Gage and Arnold Pizer receive 2016 AMS Impact Award

AMERICAN MATHEMATICAL SOCIETY

f t ᔆ ⑤ | SHARE | 🖶 PRINT ✉ E-MAIL

Michael Gage and Arnold Pizer, both of the University of Rochester, have received the 2016 American Mathematical Society (AMS)

"honored for the creation and development of WeBWorK, one of the first web-based systems that assign and grade homework problems in mathematics and science courses."

"WeBWork is the most successful online homework system that is non-profit, free, open source, and textbook/ publisher independent."

tremendous resource now used in mathematics classes across the country. This is an outstanding example of mathematicians serving the needs of mathematics

nominated by Sema Salur

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.

OpenProblemLibrary and Library browser

- How the library browser works for selecting new problems. (Demo)

- The global and local statistics shown are the beginning of our attempt to analyze the data that is collected by WeBWorK.

- The OpenProblemLibrary (OPL) and OPL editorial workshops deserve their own story.

- Over time WeBWorK is likely produce one of 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.

  - Maintaining funding for the editorial workshops is a priority.

Screen shot of library browser

Problem usage statistics in OPL

- Usage: Number of times problem used

- Attempts: Average number of attempts for success

- Status: Success rate

https://hosted2.webwork.rochester.edu/webwork2/2014_07_UR_demo/

Interoperability

The WeBWorK webservice enables these plugins

- WeBWorK and Moodle

  - **Assignment plugin** — wwassign module (1999–2015)

  - **LTI plugin** (2016) which may eventually replace wwassign

  - **Quiz plugin** — uses Hunt's Opaque client/server protocol (2007-2015) (thanks to WEPS and Mika Seppala for encouraging recent work on this)

- WeBWorK — Canvas, Blackboard, D2L,

  - **LTI plugin** provides single sign on (SSO) and grade passbook

- Mathbook XML and **HTML plugin**

  - Embed live WeBWorK problems in anything published to HTML.

https://devel3.webwork.rochester.edu/moodle
Linear Algebra/ODE course
login/password   visitor/visitor

19 January - 25 January

Using techniques of integration to find formulas for the solutions to certain differential equations.
 1. Separable equations trick.
First order linear, non-homogeneous ODE: y' +p(t)y = g(t)
 2. Undetermined coefficients trick
 3. variation of parameters (and/or integrating factor) method

READ: Text 1 (another account of this material is in sections 9.3 -9.6 of Stewart's Calculus book)

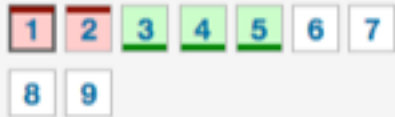Webwork1

Webwork1QuizVersion

QuizModel

Workshop 1 - plotting soltns & separation of variables method

2009 Linear Algebra and ODE course
regular webwork homework AND moodle quiz versions

Linear Algebra and ODE: Spring 2009

QUIZ NAVIGATION

1 2 3 4 5 6 7
8 9

Finish attempt ...

Start a new preview

NAVIGATION

Home
- Dashboard
▶ Site pages
▼ Current course
  ▼ spring09mth165
    ▶ Participants
    ▶ Badges
    ▶ General
    ▶ 12 January - 18 January
    19 January - 25

Question **1**

Incorrect

Mark 0.00 out of 1.00

⚑ Flag question

⚙ Edit question

WeBWorK-Moodle Question type

(Using Opaque question type)

This is the WeBWorK test Opaque engine at http://devel3.webwork.rochester.edu sessionID 15154 with question attempt 1

The solution of a certain differential equation is of the form

$$y(t) = a \exp(6t) + b \exp(10t),$$

where a and b are constants.
The solution has initial conditions $y(0) = 3$ and $y'(0) = 3$.
Find the solution by using the initial conditions to get linear equations for a and b.

$y(t) = $ ┃ 6.75 *(e^(6 *t)) + -3.75 *(e^(10 *t)) ┃

Actions

[Preview] [Submit Attempt] [Grade and Finish]

Click here to show more details

Moodle handles the presentation and quiz navigation. WeBWorK only renders the questions and evaluates the answers.

Reference links

References

- 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

Thank you

- What is the proper role of open source development for academic materials?

- How is it to be supported?

Unanswered question:

- Is WeBWorK development sustainable over the very long term?

- What is the proper role of open source development for academic materials?

- All of the following applications interoperate.

    - Sage

    - Geogebra

    - WeBWorK

    - STACK

    - TeX/LaTeX, MathJax

    - OpenStax textbooks (Open Educational Resources OER)

    - Moodle

    - …..

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.

Conditional Release
Forcing sets to only release after other sets are finished.

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.

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

Achievements
Setting up and using the Achievement system

Achievement Evaluator
Modifying and creating achievements

Achievement Items
Using achievement items

50 **Reduced Scoring**

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 <u>hardcopy</u> 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   Blobs

- 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….?

- 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

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?