PlanetMath Redux: Web 2.0 infrastructure for mathematical problem solving

Joseph Corneli[1], Constantin Jucovschi[2], and Alexander Mikroyannidis[1]

[1] Knowledge Media Institute, The Open University, MK7 6AA, UK
[2] The KWARC Research Group, Jacobs University, D-28759 Bremen, Germany

Abstract. This paper describes work in progress on a Web 2.0 platform offering support for informal study of mathematics. Our aim is to make undergraduate-level mathematics easier to learn: our strategy is to link problems and solved examples to prerequisite material drawn from an existing free/open mathematical knowledge repository, the encyclopedia at PlanetMath.org.

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1 Introduction

We are building a new web infrastructure for mathematical problem solving, with the aim of making undergraduate-level mathematics easier to learn. Our strategy is to build a layer of contributed problems and solutions that are linked and cross-referenced with the peer-produced mathematics encyclopedia developed and hosted on PlanetMath.org[3].

PlanetMath has been an active content-producing community since 2001, with around 300 authors contributing to an encyclopedia defining more than 15000 mathematical concepts. Support for problem solving will alter the space significantly, making it easier for students to contribute, and opening up new channels for peer tutoring.

The knowledge rich, systematically constructed, peer reviewed encyclopedia will supplement problem sets with background material that undergraduate students will not find in online mathematics learning environments like OpenStudy[4], Khan Academy[5], MathOverflow[6], or the Math Forum's Virtual Math Teams[7], though we draw ideas and inspiration from each of these projects.

Some of the core strengths of our system will be:

– A low floor (easy to participate just by asking a question: keywords will be automatically linked to their definitions) and a high ceiling (the possibility to explore advanced topics and help others);

[3] http://planetmath.org
[4] http://openstudy.com
[5] http://www.khanacademy.org
[6] http://mathoverflow.net
[7] http://vmt.mathforum.org/vmt/

- Simple models of learning (vocabulary acquisition, situational/relational data like "working at the cutting edge" or "helping others", and use of identified problem-solving heuristics), which will help us keep track of students progress, making the system suitable for peer-supported self-study [1];
- Teachers will be able to use the site to run their own courses (cf. earlier classroom experiments by David Smith [8] and Robert Milson [5]);
- Solutions will be available to logged in users only;
- Activity tracking can be used to identify abuses, and, more importantly, data mined to make recommendations and generate new heuristics for learning and problem solving.

The remainder of this paper will explore related work, and then describe our plans for the system's development in greater detail. The conclusion of the paper considers some of the implications of this effort for the future of mathematics education.

2 Related work

In Aaron Krowne's brief overview [4] of the principles that informed the design of PlanetMath in its original incarnation, he states:

> The basic, universal goals of digital libraries are to provide a logically organized, conveniently accessible, and (if possible) easily *actionable* collection of digitized *knowledge* in some field or fields for an audience of *learners*. (Emphasis in original.)

In moving from an encyclopedia (a reference work) to a learning environment, we extend each of these critical dimensions: the resource becomes more directly useful, it includes new kinds of knowledge, and it is accessible to a wider population of learners.

Work from the same era in the ARIADNE project [6] gives a loose typology of the kinds of interactions that can occur in a digital library: user-user, user-staff, staff-staff. Although PlanetMath does not currently have a staff per se, the addition of a problem solving focus does create an interesting mixed model, where tutorial sessions feed into the knowledge base. This avenue brings with it a business model that has been lacking in the past decade at PlanetMath. We're interested in exploring use of real-time technologies like Etherpad and Skype to support tutorials. (OpenStudy experimented with an in-house Etherpad derivative called StudyPad, though it is no longer actively used on their site.)

Contemporary approaches to building OER repositories of which we are aware (e.g. Rice University's Connexions project[8], the Open University's OpenLearn[9], or MIT's Open CourseWare project[10]) tend not to emphasise learner-produced materials. Our proposed combination of a largely learner-produced

[8] `http://cnx.org`
[9] `http://openlearn.open.ac.uk`
[10] `http://ocw.mit.edu`

OER and the orientation towards encyclopedic completeness in this project seem to be unprecedented, at least in the online space. In the print world, we might find some parallels in Springer's popular Graduate Texts in Mathematics series, or even Bourbaki's series of textbooks, but the strategy of peer-producing a comprehensive collection of learning materials seems novel, and affords quite a few new opportunities. The earlier effort in the Free High School Science Texts project[11] may present an intermediate point in the spectrum, though, again, student- or learner-produced materials were not emphasised.

As the project matures, we expect to hear a variety of differing opinions about the sensibility and utility of this approach, similar to the voices in the now-classic debate over the use of graphing calculators or computers in mathematics classrooms. Questions about how to learn best in a knowledge-rich setting are not yet well understood.

Our project connects with another contemporary effort to understand and develop software support for dealing with massive amounts of knowledge, namely the Linked Data strategy. We plan to make all of our materials available as Linked Data, which will enable downstream users to remix the repository's contents with sources from external Linked Data repositories, like DBpedia. Where it seems relevant, we may pursue content sharing arrangements with other other mathematics projects who use a compatible license (e.g. ProofWiki[12] and MathOverflow).

Once we have access to a wide range of mathematical resources, we will be able to make useful recommendations for both self-hosted and and externally-hosted materials, following the methods of e.g. the FolkSemantic widget for OER recommendations.[13]

3 Planned features of the problem solving environment

After some initial prototyping work [3], we decided to develop the system as a collection of plugins and modules for the popular open source content management system, Drupal. The current version of the system supports core "Web 2.0" features (like editing and comments, which are also present in the legacy version of PlanetMath's software), and thanks to an OMDoc-based backend, provides a basis for subsequent semantic extensions, such as term disambiguation and linking within formulas.

In addition to a port of legacy PlanetMath features and content into the Drupal framework, we are developing these new features to support problem solving:

(1) Autolinking of technical terms from problems and solutions into the PlanetMath encyclopedia (adapting [2]);
(2) learner profiles and basic activity logging, keeping track of

[11] `http://www.fhsst.org`
[12] `http://proofwiki.org`
[13] `http://www.folksemantic.com/widgets`

(i) vocabulary acquisition (technical terms used in any contributed texts, and "correct" usage based on peer review of solutions)
(ii) situational/relational data (e.g. introducing new words into the system, offering help to others, bookmarking a piece of content in the encyclopedia, looking at solutions, etc.)
(iii) heuristic use (via textual analysis and/or special-purpose discourse markers to denote reasoning steps in proofs or problems, e.g. "by analogy with" or "examining the simpler case").

(3) Recommendations based on further textual and hypertextual analysis, to suggest simpler or harder problems, related expository writings, and relevant reasoning steps.

We're aware that there are many existing repositories of problems (in textbooks, lecture notes, and other sources), and we hope to encourage authors to contribute their problems into our repository by providing long-term storage, dissemination, and maintenance, as well as improvements like cross-linking the problems with expository material in the encyclopedia.

We plan to add support for problems written in a simple automatic marking facility, (e.g. STACK[14], WeBWork [7]), from which automatic assessment (for multiple choice style problems) can be obtained. This will be useful for creating some "standardised testing" to accompany the nonlinear, distributed, self-directed learning processes.

Finally, we also also plan to add support for tangibly interactive problems-cum-learning objects, e.g. written in HTML5 (compare the Flash interactives in the National Schools Observatory[15] and the beautiful examples on WorryDreams[16]).

4 Conclusion

The realized system is anticipated to help cut time and other costs for both learners and teachers, by being a source of problems and solved examples, cross-referenced with prerequisite readings, all of which can be remixed in purpose-made study guides. We expect that our approach to knowledge reuse and peer-to-peer learning will be applicable in related technical fields.

It seems to us that moving the kinds of resources usually found in textbooks into an online, peer-to-peer, context changes the meaning and dynamic of their use. For example, while it is entirely reasonable to suggest that students must solve problems with a high degree of independence in order to learn deeply, in the context of "PlanetMath Redux", it is not clear that we should require the same style of independent learning from all users. Some may prefer to browse textbook solutions and move on to applications; others may be interested in looking for simpler derivations, or expanding existing solutions with deeper formality or nice

[14] `http://www.stack.bham.ac.uk`
[15] `http://www.schoolsobservatory.org.uk`
[16] `http://worrydreams.com`

graphics. We feel that all of these contributions are interesting and useful, and we feel we can look forward another exciting decade of "math for the people, by the people" on PlanetMath.

References

1. Corneli, J., and Ponti, M.: Detecting mathematics learning online (preprint available at `http://metameso.org/~joe/docs/detecting-learning.doc`)
2. Gardner, J., Krowne, A., and Xiong, L.: NNexus: An automatic linker for collaborative web-based corpora, IEEE Transactions on Knowledge and Data Engineering, 21(6), 829-839, 2009.
3. Kohlhase, M., Corneli, J., David, C., Ginev, D., Jucovschi, C., Kohlhase, A., Lange, C., Matican, B., Mirea, S., and Zholudev, V.: The Planetary System: Web 3.0 & Active Documents for STEM, in Proceedings of the International Conference on Computational Science, ICCS 2011, Nanyang Technological University, Singapore, 598-607, 2011
4. Krowne, A.: Building a Digital Library the Commons-based Peer Production Way, D-Lib Magazine, 9, 2003
5. Milson, R., and Krowne, A.: Adapting CBPP platforms for instructional use, in M. Halbert, ed., Free Culture and the Digital Library Symposium Proceedings, pp. 255-272, 2005.
6. Nichols, D. M. and Twidale, M. B.: Computer supported cooperative work and libraries, Vine, 109, 10-15, 1999.
7. Segalla, A. and Hauk, S.: Using WeBWorK in an Online Course Environment, Journal of Research in Innovative Teaching, 1, 128-144, 2008
8. Smith, David A.: How People Learn... Mathematics, in Proceedings of the International Conference on the Teaching of Mathematics (at the Undergraduate Level), Hersonissos, Crete, Greece, July 1-6, 2002.