Crowdsourcing a Personalized Learning Environment for Mathematics

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Abstract. Can we build a semantically adaptive personal learning environment that helps people learn mathematics and that meets reasonable criteria for sustainable growth and development? This is question that applies at the interface between participatory social media and interactive, adaptive, "knowledge media". Ten years ago, no one had heard of Wikipedia. Perhaps in another ten, P2PU will be as popular as my home institution, The Open University. A wide range of stakeholders in education are surely curious to know why, or why not, and what this may mean for their careers. Aside from the possible social significance of the question, I anticipate that the personal learning environment (PLE) approach will provide an interesting stream of use data, including implicit and explicit information about how people learn mathematics. This opportunity to look in detail at learning behaviour in open, online, participatory, educational spaces is quite new. My project will combine socio-cultural analysis, technical development work, and datamining techniques to help support both individualized learning and ongoing system development.

Key words: crowdsourcing, personal learning environments, mathematics

1 Roadmap

How do people learn mathematics? What motivates people to learn in one way or another, given that it's not often easy? Here we recall Euclid's warning: "there is no Royal Road to geometry." Even so, we can imagine a *road to free math* (Figure 1)!

Just what does "free" mean in this context? I think it entails understanding the ambitions of the people involved, as well as their frustrations. Learning math may not be "easy", but perhaps it can be *free of unnecessary frustrations*. My approach aims to foster learner self-awareness and a realistic sense of what's possible. In the words of C. S. Pierce, "To know what we think, to be masters of our own meaning, will make a solid foundation for great and weighty thought."[1]

2 Review of Existing Research

As a sort of mantra, it is helpful to return to the view of personal learning environment put forward by the progenitors of the PLE concept: "Rather than

Fig. 1. The Road to Free Math

integrate tools within a single context, the system should focus instead on co-ordinating connections between the user and a wide range of services offered by organizations and other individuals." (Wilson et al., 2006) [2].

The key idea here is that learning takes place in a complex "ecosystem". Rather than building monolithic, or even modular, educational structures, in their fullest development, PLEs will support fully distributed, decentralized, perhaps even "organic", learning activities. With this vision in mind, it is still useful to remember that all activities take place in some context (more on this in Section 4).

Cormac Lawler's research (e.g. [3], [4]) indicates some of the challenges inherent to collaboratively producing a given online space to support learning. In particular, Lawler's attention to the bottom-up nature of Wikiversity provides an important contrast to the top-down nature of systems-engineering (a quality that applies even to systems with significant distributed aspects).

Aaron Krowne's master's thesis [5] details his development of a system for the collaborative production of digital libraries (such as the now-popular PlanetMath.org). In a subsequent collaboration with the present author, these ideas of "commons-based peer production" are connected to various historical developments in hypertext [6]. The system's usefulness in an instructional context is discussed in Milson and Krowne [7], which incidentally also includes numerous citations to earlier literature on collaborative and online learning.

So, what's the hold-up? (If, indeed, there is a hold-up.) My sense is that whether we are talking about engineered, democratic, or distributed solutions (and we're typically always talking about a combination of all of these), what remains in very short supply is the multi-level, multi-scale adaptability that could actually change a learning ecosystem. It is perhaps especially important to overcome the "learner-centric" model that is so popular these days (and is still clearly felt in the quote from Wilson *et al.* above). Or else, putting it another way, to admit once and for all that we're all learning – and that, as they say, we all make mistakes.

Although there have been many academic and commercial projects that successfully solve problems on behalf of learners, uptake or buy-in has often been lacking (ActiveMath makes a particularly good example [8]), or else cost remains prohibitive and major extensions are difficult or impossible to make (e.g. Mathematica). These are the problems I aim to tackle in my work.

3 Research question

Can we build a semantically adaptive personal learning environment that helps people learn mathematics and that meets reasonable criteria for sustainable growth and development?

3.1 Development of the Research Question

Our aim is to build a lens for looking at mathematical learning behaviour in detail. There are several criteria required for "success".

1. It is essential that enough people are motivated to use the system.
2. It is essential that at least some of them learn mathematics while using the system.
3. We will need to document how the semantic adaptivity and personalization features, in specific, help people learn.
4. We will require evidence that the system will grow, not stagnate.

4 Specification of Research Approach

Building educational systems online, in the open, we hope to exploit both high-intensity, high-cost contributions, and a long tail of smaller and less intensive contributions. The process of assimilating many small contributions into resources of high-quality – colloquially known as "crowdsourcing" – forms part of a possible solution to the "sustainability problem". But, like "open source", crowdsourcing is not a panacea. Section 4.1 presents two approaches that I think can be applied to make crowdsourcing work well.

4.1 Situation relative to contemporary theory

In preparation for dealing with the issues I expect to come up in, I've been developing some (interrelated) themes having to do with the ideas of *shared context in motion* and *sensemaking*.

Nishida's idea of shared context in motion, or *basho* [9], as filtered through the the "SECI" framework of Nonaka and Toyama [10], can help us move from stakeholder groups to a clearer picture of the roles of actual participants and on to a detailed understanding of the activities which support these roles (e.g. a student's activities include going to class, collaborating on a class project, building a transcript, and ultimately gaining a skill). Activity theory seems to pick up where SECI leaves off, as it provides another Nishida-like way to "understand the unity of consciousness and activity" ([11], p. 7). These ideas will be used on an ongoing basis to create increasingly detailed sketches of the activities we would like to support.

Sensemaking is a methodology for finding and filling gaps. There is both an extensive research literature (cf. [12]) and room for new and creative ideas connecting to an interesting philosophical tradition (what does it mean for things to "make sense"? cf. [13]). I hope to use sensemaking as a way to move back and forth between high-level picture coming from SECI analysis and detailed development issues, finding ways in which "various data elements fit together in a coherent causal scheme", helping understand how to actually support the activities we're interested in (see Klein *et al.*, [14], [15]).

4.2 Summary of development goals

It is worth noting that the approaches described above work in a context where it is assumed that that much of what happens *happens elsewhere*, i.e., where we do not presume to be the only show in town. We will not aim to be all things to all people, but to gather enough information to do useful research about what how PLEs can help people learn mathematics. To do this well, we'll want a system should be compatible with various ways of learning and doing mathematics.

Planetary is the name of a system that is currently under development, which meets these needs.[1] Planetary began as a collaboration between myself, Catalin David, Deyan Ginev, and Michael Kohlhase at Jacobs University, with the goal of creating an easy-to-extend clone of PlanetMath's software platform "Noösphere". We chose to base the system on the popular open source Vanilla Forums[2], and the first set of extensions added mathematical writing and rendering capabilities using LaTeXML[3]. Subsequent extensions – all pure plugins to Vanilla – have begun to integrate the "KWARC stack" of software tools for working with mathematics with semantic markup.[4]

My development goals are to

A. finish the clone phase and port the legacy PlanetMath content to the new platform as quickly as possible;
B. add tools for authoring and solving interactive exercises, so as to begin gathering data and generating recommendations based on the learner's performance and prior knowledge;
C. add various other useful plugins that make the site useful and attractive (e.g. integrating the SAGE computer algebra system, the Geogebra diagram-creating system, and a maths-enabled version of Etherpad);
D. move in the direction of increased compatibility with other ways of interacting with mathematics online (e.g. compatibility with Wikipedia, ArXiv, Mizar).

5 Conclusion

The problem I've posed asks how to make large-scale computer-mediated learning system sustainable (something that has arguably not been done before, at least apart from "the free/open source software movement" taken as a whole). This is an ongoing challenge that I hope many people will help solve. A contribution that I feel is more uniquely my own will be an improved understanding of how people learn mathematics, discovered in patterns found via data mining, and embodied in adaptive recommendation algorithms.

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[1] http://trac.mathweb.org/planetary
[2] http://vanillaforums.org
[3] http://dlmf.nist.gov/LaTeXML/
[4] http://kwarc.info

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