Learning trajectories in Open Source Software: Implications for designing problem-based learning experiences in support of higher order thinking

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Problem Statement

Note: Faculty development paper has sources that say real-world experience is a factor in attracting women to computing.

A general problem in CE is that it still focuses mainly on knowledge acquisition, while effective practice relies on effective problem solving. (O'Grady). As well, CE has seen a decline in enrollment of students (stats here) as well as issues with retention and a lack of women and minority participation. Problem-based learning has been touted as a learning experience that helps with development of higher-order thinking skills and has been proposed by many as approach that should be taken for computing education. (refs) Besides cognitive skill development, proposed affective learning aspects of PBL include increased motivation generated by the problem challenge and satisfaction from participation in an authentic, applied learning exercise. Wider spread adoption of PBL may help not only development of the cognitive higher-order skills that may affect retention in the major, but also with the affective aspects such as motivation and interest that may impact attraction to the field. (refs)

However, despite these claims little adoption of PBL in CE has occurred because institutional and pedagogical reasons; this research proposal focuses on addressing pedagogy and learning outcomes. Regarding instruction there's the difficulty of developing adequate problems and the lack of instructional design prescriptions to support structuring the PBL process. (Clark, O'Kelly) What if there existed a ready-made learning environment that provided authentic problems for students to learn from that may also provide some of the support structure needed for PBL? Open source software systems, as informal learning environments, have the potential to do so.

Paragraph on FOSS and how can support PBL..

However, while there has been some student participation in FOSS for CE there is a lack of instructional design support, lack of rigorous measure of skills exercised and learning outcomes. This research proposes to study FOSS communities to identify the resources provided that support PBL activities and their relationship to higher-order skill learning practice. This research will be used to influence the instructional design of PBL-based learning activities in support of higher-order thinking skill development. Success in achieving learning objectives will be determined through testing of activities with undergraduate computing students.

Vision statement (wrap it up)

RQs

1. What opportunities does FOSS community participation provide to exercise higher-level thinking skills? What is relationship to resources provided by the community and those opportunities (e.g., tasks, technology, community)?
2. What resources (tasks, technology, community) can be leveraged as part of a PBL instructional design assist with the development of higher-order thinking skills while satisfying CE learning goals?

Lit review

RQ 1- What opportunities does FOSS community participation provide to exercise higher-level thinking skills? What is relationship to resources provided by the community (e.g., tasks, technology, community)?

State of PBL in CE (adoption, empirical study in relation to HOT skill development)

What is PBL, why PBL?

Problem-based learning (PBL) an instructional model based on constructivist learning theory, which describes the learning process as "*meaning making* … rooted in the context of the situation." Benefits of constructivist-based learning design include engagement in authentic activities that relate to how people actually learn, higher-order learning outcomes, integration of affect and emotion leading to less "academic" more expertise-related discussion, and better transfer of skills outside the academic setting. (Wilson)

Constructivism has three central tenets: 1) Understanding comes from interacting with the environment, 2) the stimulus for learning comes from problems which in turn direct the learning process; and 3) knowledge is derived through social interactions. (Savery 01) Savery 01 lists instructional principles following from this philosophy, noting that among the many learning environments, PBL addresses these most closely:

1. **Anchor all learning to a larger task or problem-** learning must have a purpose for the learner.
2. **Support the learner in developing ownership for the overall problem or task –**align learner goals with instructional goals
3. **Design an authentic task-**the cognitive demands should align with the cognitive demands where the learner will perform ultimately.
4. **Design the task and the learning environment to reflect the complexity of the environment they will function in at the end of learning**
5. **Give the learner ownership of the process used to develop a solution-**don't simplify the environment, but support the student within the complex environment
6. **Design the learning environment to support and challenge the learner's thinking-** don't "proceduralize" how the student approaches solving the problem.
7. **Encourage testing ideas against alternative views and alternative contexts-**Because knowledge is socially constructed, interactions in collaborative group can be used to test individual understanding.
8. **Provide opportunity for and support reflection on both the content learned and the learning process**

Problem-based learning is conducted in small collaborative groups working on realistic ill-structured problems). The teacher acts as a facilitator guiding the learning process helping them learn the cognitive skills involved in problem solving and collaboration. Student groups analyze and define the problem by identifying the important components of the problem scenario. From there, they generate hypotheses of how to solve the problem. During this process self-directed learning is employed as students encounter gaps in knowledge. From there they apply their new knowledge, evaluate their hypotheses and reflect on what they've learned. For students to be successful they must learn how to be self-directed learners which requires they be reflective and apply critical thinking about what they are learning. (04 Hmelo-Silver)

In general, it has been proposed that PBL helps students: 1) develop an extensive, flexible knowledge base; 2) develop problem-solving skills; 3) become self-directed learners; 4)become effective collaborators and 5) become intrinsically motivated learners. To elaborate on knowledge construction this also means students learn to connect information across multiple domains. Developing effective problem solving requires developing metacognitive and reasoning strategies. Metacognition development is important to both evaluating problem solving progress and learning progress for self-directed learning. Developing collaboration skills involves working with others to identify actions needed, come to agreements over issues and effective communication within the group and also aids in the facilitating the social aspect of learning. PBL can aid in intrinsically motivating students that through involvement in problems that are proximal and relate closely to their own learning goals. (04 Hmelo-Silver)

Research studying learning effectiveness of PBL

Hmelo-Silver 04 reports that results from learning studies using PBL are "mixed.", although much of the evaluation has focused on outcome measures such as testing scores. Furthermore, most research has primarily been in higher education, mainly in medical schools. Of note there is evidence for more accurate hypothesis generation and development of problem solving skills due to use of hypothesis-driven reasoning and better problem identification. Studies of self-directed learning in PBL show that it depends on the learner's learning history, self-regulation of learning strategies, self-efficacy and features of the PBL environment. There has been little research on PBL effects on motivation and collaboration.

Why PBL in CE?

Problem-based learning lends itself well to computing education because computing is driven by problems; requires life-long learning to stay current with emerging technology; work is mainly done in project teams and it generally crosses multiple disciplines. (98 Ellis, 02 Aramego) In addition, while not the focus of this proposal, studies have shown also that when used in CE it may help attract more female students (04 Hamainen, 98 Barrows (need to read), improve retention (04 Hamainen), motivation (04 Hamainen, 10 Wang), and passing rates (04 Hamainen, 03 Parham).

However, CE still focuses on knowledge transmission (12 OGrady), not developing higher-order thinking or advanced reasoning skills, which are critical for a career in the computing industry (12 OGrady, 12 Exter). Effective instructional design in support of this skill development is still an open question. (12 OGrady) Furthermore, given the potential for PBL in CE to increase female enrollment (why?) and improve retention (sources) there is further reason learn how to use effectively. (need to tie PBL to females and application and retention from literature)

PBL in CE, measurement of skill development

Most literature has focused on the affective part of not cognitive

Even when attempting to measure cognitive:

Used student perceptions of what was learned

Got closer perhaps to study of cognitive with examining learning diaries and grades

But very few specifically attempted to measure HOT skills

Limitations in empirical study of PBL in CE/(limited HOT)

These studies attempt to, here are the limitations.

What other methods have been used to help generate HOT that aren't PBL?

Have they worked?

Why FOSS?

Not only does a successful PBL approach require authentic problems, but industry practitioners have also called for student exposure to authentic problems indicating that such an approach during formal education would be the best method to prepare students for work in computing. It was noted that real-world types of large projects that involve technical writing, testing, version control, and exposure to design concepts and problem solving were needed. (12 Exter)

However, a common problem expressed through literature on PBL in CE has been the difficulty in developing problems. (05 Clark, 06 OKelly) But, problems alone are not the only resources used in PBL. PBL requires many other resources to be successful: 1) facilitation, 2) subject guidance, 3) scaffolding, 4) production, 5) assessment. (98 Ellis) Open source software communities provide a ready-made pool of authentic problems that can be leveraged, and other technological and social elements that can aid in providing resources in support of PBL.

What is FOSS?

Note: See Intro in Faculty Development for FOSS in Education for more info on extent of FOSS.

There are many success stories in FOSS from Apache and Firefox to lesser known but no less important projects as those in humanitarian free and open source software. Sizes of projects in terms of contributors range from tens to thousands. As of 2008, a conservative estimate of the number of active FOSS projects was 18,000 and that it was growing at an exponential rate. (08 Deshpande – The Total Growth of Open Source)

To understand the extent of FOSS use, the internet infrastructure mostly runs on open source products. For instance, Apache Tomcat is used on over 60 percent of websites. (ref) In addition, FOSS is generally free of direct cost and traditionally better than proprietary systems in terms of portability. Given the openness of code it also generally more reliable and secure; A famous saying related to open source, "Given enough eyeballs, all bugs are shallow," attests to that. (Deek says Raymond, 1998, however check source) There is some evidence to back these claims. For instance, an empirical study of MySQL showed six times less defects than similar commercial databases (Tong, T. (2004). Free/Open Source Software in Education. United Nations Development Programme's Asia-Pacific Information Programme, Malaysia).

The open source software movement grew out of a desire to keep software innovation open, by making source code generally available, much like the intellectual style of science. (Deek 08) These projects consist of self-organizing groups of distributed contributors. Generally artifacts and process are transparent and most contribution is voluntary. However, some companies pay their workers to contribute. (Mockus 02 Deek 08) These communities often use lean media to coordinate activities and share knowledge, tools such as CVS and Git for version control of code, web sites and online tutorials for instructional content, and Internet Relay Chat (IRC) and mailing lists for communication. (08 Weller)

Why would one want to incorporate FOSS as a resource in a PBL approach? (tie back to how FOSS provides not only problems but other resources that support PBL)

If we revisit the three main tenets of constructivism one can see that learning as a participant in FOSS is a constructivist process. This is because learning within FOSS involves: 1) deriving understanding from interacting with the environment, 2) problem-solving; and 3) developing knowledge through social interaction. First, FOSS communities are authentic software development communities; learning is not occurring in a simulated environment and participants are learning as an outgrowth of their own goals within the community. Second, participation in FOSS, which can take many forms from testing to bug fix to documentation to design and development, arises out of a real need. Third, knowledge in FOSS is socially constructed through participants' inquiries to the community and reexamination of community artifacts.

To consider at a lower level how learning occurs in FOSS one can take the three themes of constructivism-- situational knowledge construction, environmental interactions, challenge—and look at those in regard to related learning theories to explicate the process. Many studies of learning in FOSS discuss it in social-constructivist terms referring to situated learning theory and the notions of communities of practice and legitimate peripheral participation. Many of these studies are interested in newcomer learning and contribution paths for participants. Overview of literature … How can be important to this study.

However, while this points to FOSS communities as environments with potential to support situated knowledge construction, examining communities based on that theory alone doesn't consider the role of practice in the community *and* reflection and conceptualization. (Hemetsberger) Drawing upon experiential learning theory (Kolb, 1984), however, Hemetsburger was able to consider concrete experience and abstract conceptualization in the

KDE project and the role of technology in those processes. This is also important because unlike social-constructivist theories which are based on face-to-face interactions such as … work and learning in FOSS communities is often an individual process (Howison, Hemetsburger) but coordinated/facilitated by technology.

Kolb's experiential learning theory is a holistic learning process that expresses how knowledge is generated through "transformation of experience." It involves concrete experience, reflective observation, abstract conceptualization, and active experimentation. (http://www.learning-theories.com/experiential-learning-kolb.html) Hemetsburger used the phases of this cycle to identify how technology used by KDE developers contributed to knowledge creation collectively and individually. Table 1 presents the technological tools, learning and knowledge building processes, and resulting knowledge artifacts generated by the KDE developers. These knowledge artifacts enable re-experience and action that permit learning and knowledge building to occur in FOSS communities. The extent of these types of knowledge artifacts contributes to the ability to leverage those as resources in the PBL process.

Table 1.

Technological Tools	Learning/knowledge building processes	Knowledge artifacts
CVS repository	Full cycle of re-experiencing: Concrete experience Reflective observation Abstract conceptualization Active experimentation	Code
Website content and hyperlinks (e.g. FAQs, content)	Productive inquiry Reflective observation	Transactive group memory
Online tutorials and screenshots	Active experimentation Reflective observation	Instructive content
IRC (Internet relay chat)	Reflective observation Collective reflection	Instructive discourse
Asynchonous communication (e.g. mailing lists, newsgroups)	Collective reflection Collective conceptualization	Reflective discourse

	Virtual experimentation*	

*Virtual experimentation refers to ideas for experimentation programmers had.

Discuss examples above in relation to learning processes.

Discuss Lin article discussing FOSS and ill-structured problems tie that to can be leveraged in PBL ID.

What is the extent of FOSS participation for learning?

What skills are developed? Discuss methodological concerns and lack of study of HO skills?

RQ 2 –

Can PBL- tailored student involvement in FOSS communities assist with the development of higher-order thinking skills while satisfying CE learning goals?

State of Instructional Design of PBL in CE

State of Instructional Design for FOSS participation in support of CE

While there has been student participation in FOSS for learning there is a lack of instructional design for using. Discuss lack of formalism from literature and many problems in applying.

Research gaps/methodological limitations

Here making a case to set up a case study of students participating in FOSS that follows an ID incorporating the PBL process to measure HO and other skill development.

Methodology

RQ1 - study of artifacts (mailing lists, IRC, etc.) related to participants' progression in FOSS to identify skills exercised, in particular HO. This will be used to tie FOSS activities to learning goals and to understand how to leverage the community and technology as part of PBL instructional design that will be tested to answer RQ2.

RQ2 - Case study of PBL instructional design of student participation in FOSS. As part of an independent study students will participate in an FOSS community. Instructor will follow PBL instructional designs developed from output of study for RQ1. Assessment will include pre and post testing of higher-order thinking skills, and evaluation of activity in the community, and student learning diaries.