Motivational Social Visualizations for Personalized E-learning

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Abstract. A large number of educational resources is now available on the Web to support both regular classroom learning and online learning. However, the abundance of available content produces at least two problems: how to help students find the most appropriate resources, and how to engage them into using these resources and benefiting from them. Personalized and social learning have been suggested as potential methods for addressing these problems. Our work presented in this paper attempts to combine the ideas of personalized and social learning. We introduce Progressor⁺, an innovative Web-based interface that helps students find the most relevant resources in a large collection of self-assessment questions and programming examples. We also present the results of a classroom study of the Progressor⁺ in an undergraduate class. The data revealed the motivational impact of the personalized social guidance provided by the system in the target context. The interface encouraged students to explore more educational resources and motivated them to do some work ahead of the course schedule. The increase in diversity of explored content resulted in improving students' problem solving success. A deeper analysis of the social guidance mechanism revealed that it is based on the leading behavior of the strong students, who discovered the most relevant resources and created trails for weaker students to follow. The study results also demonstrate that students were more engaged with the system: they spent more time in working with self-assessment questions and annotated examples, attempted more questions, and achieved higher success rates in answering them.

Keywords: social visualization, open student modeling, visualization, personalized e-learning

1 Introduction

A large number of educational resources is now available on the Web to support both regular classroom learning and online learning. However, the abundance of available content produces at least two problems: how to help students find the most appropriate resources, and how to engage them into using these resources and benefiting from them. To address these problems a number of projects have explored personalized and social technologies. Personalized learning has been suggested as an approach to help every learner find the most relevant and useful content given the learner's current state of knowledge and interests [1]. Social learning was explored as a potential solution to a range of problems, including student motivation to learn [2-5]. In our group's earlier work, these approaches were explored in two systems, QuizGuide [6] and Knowledge Sea II [7]. QuizGuide provides topic-based adaptive navigation support for personalized guidance for programming problems. Knowledge Sea II uses social navigation support to help students navigate weekly reading assignments. These and similar systems demonstrated the value and effectiveness of personalized learning and social learning in E-Learning. However, the combination of these powerful approaches has not been seriously investigated. The work presented in this paper attempts to explore the value of a specific combination of personalized learning and social learning to guide students to the most relevant resources in a course-sized volume of educational content.

2 Related Work

2.1 Open student modeling

The research on open student modeling explores the value of making students models visible to, and even editable by, the students themselves. There are two main streams of work on open student modeling. One stream focuses on visualizing the models supporting students' self-reflection and planning; the other one encourages students to participate in the modeling process, such as engaging students through the negotiation or collaboration on construction of the model [8]. Representations of the student models vary from displaying high-level summaries (such as skill meters) to complex concept maps or Bayesian networks. A range of benefits have been reported on opening the student models to the learners, such as increasing the learner's awareness of knowledge development, difficulties and the learning process, and students' engagement, motivation, and knowledge reflection [8-10]. Dimitrova et al. [11] explored interactive open learner modeling by engaging learners to negotiate with the system during the modeling process. Chen et al. [12] investigated active open learner models in order to motivate learners to improve their academic performance. Both individual and group open learner models were studied and demonstrated increased reflection and helpful interactions among teammates. Bull & Kay [13] developed a framework to apply open user models in adaptive learning environments and provided many in-depth examples. Studies also show that students have a range of preferences for how open student modeling systems should present their own knowledge. Students highly value having multiple viewing options and being able to select the one with which they are most comfortable. Such results are promising for potentially increasing the quality of reflection on their own knowledge [14]. In our own work on the QuizGuide system [6] we combined open learning models with adaptive link annotation and demonstrated that this arrangement can remarkably increase student motivation to work with non-mandatory educational content.

2.2 Social navigation and visualization for E-learning

According to Vygotsky's Social Development Theory [15], social interactions affect the process of cognitive development. The Zone of Proximal Development, where learning occurs, is the distance between a student's ability to perform a task under adult guidance and/or with peer collaboration and the student's ability to solve the problem independently. Research on social learning has confirmed that it enhances the learning outcomes across a wide spectrum, including: better performance, better motivation, higher test scores and level of achievement, development of high level thinking skills, higher student satisfaction, self-esteem, attitude and retention in academic programs [16-18].

To support social learning, a visual approach is a common technique used to represent or organize multiple students' data in an informative way. For instance, social navigation, which is a set of methods for organizing users' explicit and implicit feedback for supporting information navigation [19]. Such a technique attempts to support a known social phenomenon where people tend to follow the "footprints" of other people [7, 20, 21]. The educational value has been confirmed in several studies [22-24]. The *group performance visualization* has been used to support the collaboration between learners among the same group, and to foster competition in groups of learners [25]. Vassileva and Sun [25] investigated the community visualization in online communities. They found that social visualization allows peer-recognition and provides students the opportunity to build trust in others and in the group. CourseVis [26] pioneered extensive *graphical performance visualization* for teachers and learners. This helps instructors to identify problems early on, and to prevent some of the common problems in distance learning. A promising, but rarely explored approach is social visualization of open student and group models. Bull and Britland [27] used OLMlets to research the problem of facilitating group collaboration and competition. The results demonstrated that selectively showing the models to their peers increases the discussion among students and encourages them to start working sooner. Our work presented below attempts to further advance this approach.

2.3 Social comparison

According to *social comparison* theory [28], people tend to compare their achievements and performance with people who they think are similar to them in some way. There are three motives that drive one to compare him/herself to others, namely, self-evaluation, self-enhancement, and self-improvement. The occurrence of these three motives depends on the comparison targets, they are respectively lateral comparison, downward comparison and upward comparison. Earlier social comparison studies [29] demonstrated that students were inclined to select challenging tasks among easy, challenging and hard tasks by being exposed to the proper social comparison conditions. Feldman and Ruble (1977) [30] argued that age differences resulted in different competence and skills in terms of social comparison. As young children grow older, they become more assured of the general competence of their social comparing skills [30]. Later studies showed that social comparison, prompted by the graphical feedback tool, decreases *social loafing* and increases productivity [31]. A synthesis review of years social comparison studies summarized that upward comparisons in the classroom often lead to better performances [32]. Among fifty years of social comparison theory literature, most of the work has been done with qualitative studies by interviews, questionnaires and observation. In this research, we develop a set of quantitative measures for investigating social comparison theory in our target context.

Fig 1. Progressor+: the tabular open social student modeling visualization interfaces. The open social student model visualization allows collapsing the visualization parts that are out of focus (bottom left) and also provides direct content access (bottom right)

3 Progressor+ - An Open Social Student Modeling Interface

In past studies, we explored two open social student modeling interfaces, QuizMap [33] and Progressor [34], to examine the feasibility and the impact of a combined social visualization and open student modeling approach. Both systems use open social student modeling to provide personalized access to one specific kind of learning content – parameterized programming questions for Java. The use of a single kind of context allowed us to ignore the potential complexity of diverse learning content and focus on exploring critical aspects of open social student modeling. At the same time, this meant were unable to explore the scalability of the approach, i.e., its ability to work in a more typical e-learning context where many kinds of learning content may be used in parallel. The goal of Progressor+ was to bring our earlier findings up to scale and explore the feasibility of open social student modeling in the context of more diverse learning content. To achieve this goal, we piloted a new scalable tabular interface to accommodate diverse content. The Progressor+ system interface is presented in Fig. 1. Each student's model is represented as several rows of a large table with each row corresponding to one kind of learning content and each column corresponding to a course topic. The study presented in this paper has been performed with two kinds of learning content – Java programming questions and Java code examples (thus Figure 1 shows two rows for each student - quiz progress row and example progress row), however, the tabular nature of the proposed interface allows adding more kinds of content when necessary. Each cell is colored coded showing student's progress of the topic. We used a ten-color scheme to represent percentile of the progress. The use of color-coding allows collapsing table rows that are out of focus thus making it possible to present a progress picture of a large class in a relatively small space. This feature was inspired by the TableLens visualization, which is known as highly expressive and scalable [35]. While the interface of Progressor+ was fully redesigned, it implemented most critical successful features discovered in our past studies that we review below.

Sequence: the sequence of the topics provides direction for the students to progress through the course. It also provides flexibility to explore further topics or redo already covered topics. In the QuizMap study [33], the topic arrangement in the treemap visualization was non-sequential. A key issue that emerged was that students had difficulty connecting the course structure and the treemap layout. We improved the design by providing a clear sequence in progressing through the topics in Parallel IntrospectiveViews [36] and Progressor [34] studies. We discovered that students benefited from the guidance offered by the course structure and explored more diverse topics that were appropriate for them at the moment. From these studies we also learned that topic-based personalization in open social student modeling worked more effectively when a sequence feature was implemented. In addition, we have also found that strong students tended to explore ahead of the class and weak students tended to follow them, even for the topics that were beyond the current scope. Therefore, we decided to maintain the "sequence" as one of the important features in Progressor+.

Identity: identity captures all the information belonging to the student. It is the representation of the student's unique model as well as one of the main entrances to interaction with the domain content. From the QuizMap study [33], we learned that distinguishing aspects of student's own model from the rest of the student models is not enough. This addressed the differences between the student herself and the rest of the class, but it did not carve out a clear model unit that belonged to the student. As we discovered, it is also important to offer a holistic view of individual student progress. In the Parallel IntrospectiveViews [36] study, we utilized the concept of *unity*, which proposed that perception of identity is higher if the model represents unity. This concept makes the students identify themselves with the model and allows them to easily compare themselves each other [12, 13]. In Progressor+, we believe that the simple rows & columns table representation is cohesive and can be easily shown in fragments and recognized as units. Such characteristics could promote the notion of students' identity when interacting with the system.

Interactivity: interactivity in the visualization of the user model can be implemented in several forms. Based on past studies, we knew that students benefited a lot from accessing content by directly clicking on the student's own model. The idea is simple but effective; the visualization of the user model is not a secondary widget but the main entrance allowing the students to access content directly. Moreover, students are also enabled to interact with content through their peers' models, or interact with their peers by comparing and sorting their performances. In Progressor^{+}, the core interactivity is to allow the students to access the content resources directly by clicking on the students' models - the table cells. Meanwhile, other interactivity features are, for example, a collapse-and-expand function allowing the user model visualization to deal with the complexity and the large topic domains [37], or a manipulation function allowing the user to feel in control over his/her model [38].

Comparison: letting students compare themselves with each other is the key for encouraging more work and better performance [32]. In [33, 34, 39], we found evidence that students interacted through their peers' models. Moreover, the same principle stems from the underlying supporting theory of *Social Comparison*. We believe that socially exposing models implicitly forces the students to perform comparison cognitively. We also learned that lowering the cognitive loads for comparisons could encourage more interactions. Thus, we capitalize our past successful experiences and implement different levels of comparisons: macro- and micro-comparisons. Macro-level comparison allows students to view their own models while at the same time seeing thumbnails of their peers' models. It provides a high level of comparisons, allowing fast mental overlapping of the colored areas between models. Micro-level comparisons occur at the moment a student clicks on any peer models. Progressor^{+} enters in the comparison mode by collapsing the rest of the table rows and displaying the selected peer model with all its details. Both levels of comparison allow students to perform social comparisons at their own free will.

4 Evaluation & Results

To assess the impact of our technology, we have conducted the evaluation in a semester-long classroom study. The study was performed in an undergraduate Object-Oriented Programming course offered by the School of Information Sciences, University of Pittsburgh in the Spring semester of 2012. The system was introduced to the class at the third week of the course and served as a non-mandatory course tool over the entire semester period. Out of 56 students enrolled in the course, 3 withdrew early and 38 out of the remaining 53 were actively using the system. All student activity with the system was recorded. For every student attempt to answer a question or explore an example, the system stored a timestamp, the user's name, the session ids, and content reference (question id and result for questions, example id and explored line number for examples). We also recorded the frequency and the timing of student model access and the peer comparisons. Pre-test and post-test were administered at the beginning and the end of the semester to measure students' initial knowledge and knowledge gain.

Following our prior experience with open student modeling in JavaGuide [40] and Progressor [34], we hypothesized that the ability to view students' models would motivate the students to have more interactions with the system. In particular, we expected that the motivation to work learning content would extend to both kinds of educational content, as in its earlier observed increase in the context of single-kind content collection. To evaluate these hypotheses, we compared the student content usage in three semester long classes that used three kinds of interfaces to access the same collection of annotated examples and self-assessment questions: (1) a combination of a traditional course portal for example access with an adaptive hypermedia system JavaGuide for question access (Column 1 in Table 1); [41] a combination of a traditional course portal for example access and social visualization (Progressor) for question access (Column 2 in Table 1); and (3) an open social student modeling visualization to access both examples and questions through Progressor⁺ (Column 3 in Table 1). To discuss the impact on students' motivation and problem solving success, we measure the quantity of work (the amount of examples, lines and questions), *Course Coverage* (the distinct numbers of topics, example, lines and questions) and *Success Rate* (the percentage of correctly answered questions). Table 1 summarizes the system usage for the same set of examples and quizzes in three different conditions.

Table 1. Summary of system usage for three different technologies.

		JavaGuide	**Progressor**	**Progressor⁺**
Example	N	20	7	35
Quantity	Example	19.75	28.71	27.37
	Line	116.6	219.71	184.18
	Session	5.35	5.50	4.94
Coverage	Distinct Topic	9.15	12.28	12.20
	Distinct Examples	17.3	25.13	27.37
	Distinct Lines	67.1	115.22	141.5
Quiz	N	22	30	38
Quantity	Attempt	125.50	205.73	190.42
	Success	58.31%	68.39%	71.20%
	Session	4.14	8.4	5.18
Coverage	Distinct Topic	11.77	11.47	12.92
	Distinct Questions	46.18	52.7	61.84

4.1 Effects on system usage

Among 53 registered students, 35 students explored the annotated examples and 38 students worked with self-assessment questions through Progressor⁺. On average, students explored 27.37 examples; accessed 184.18 annotated lines and answered 190.42 questions. We found that there was 38.58%, 57.95% and 51.73% more examples, lines explored and questions answered correspondingly in Progressor$^+$ compared to JavaGuide. Although we did not register a significant increase on the usage in Progressor$^+$, this still shows that the access through open social student modeling visualization is at least as good as knowledge-based adaptive navigation support, which is considered as a golden standard of personalized information access. As we anticipated, we did not find significant differences in the amount of work done between Progressor and Progressor$^+$. This demonstrates that Progressor$^+$ was as engaging as Progressor. i.e., the registered increase in the usage of annotated examples did not caused a decrease the self-assessment quizzes usage. Instead, the overall volume of work increased. The quantity results show that open social student modeling that integrates several kinds of content is a valid approach to providing navigational support for multiple kinds of educational content.

In order to demonstrate that our approach is not only valid but also capable of delivering added value, we used other parameters to measure students' learning quality. First, we calculated the number of distinct topics, examples, lines and questions attempted by the student to measure the *Course Coverage*. We found that students were able to explore more topics, examples, lines and questions by using Progressor$^+$ than the other two systems. In fact, students explored significantly more distinct lines in Progressor$^+$ than with JavaGuide condition, $F(1, 53)= 9.72$, $p<.01$. It suggests that the inclusion of the additional content (examples) into the open social student modeling visualization generated an expected increase of motivation to work with examples while maintaining the motivation to work with questions. However, was it necessary for students to get exposed to more educational content? Was the new technology able to guide students to the right content at the right time? To answer these questions, we have to examine the impact of this technology on students' learning.

4.2 Impacts on students' learning and problem solving success

To evaluate students' learning activities, we measured students' pre- and post- tests scores for knowledge gain and used the *Success Rate* to gauge students' problem solving success. Progressor$^+$ was provided as a non-mandatory tool for the course, and students were able to learn from other factors, such as assignments, lab exercises etc. Thus, in our target content, it is important to use another parameter to infer students' learning. We chose to measure students' problem solving success. Note that problem solving is an important skill acquired by learning. It has been demonstrated that it could enhance the transfer of concepts to new problems, yield better learning results, make acquired knowledge more readily available and applicable (especially in new contexts), etc. [42, 43].

We found that the students who used Progressor$^+$ achieved significantly higher post-test scores (M=15.0, SD=0.6) than their pre-test scores (M=3.2, SD=0.5), $t(37)$= 17.276, $p<.01$. In addition, we also found that the more example lines the students explored, the higher level of knowledge they gained (r=0.492, $p<.01$). With open social student modeling visualization, students also achieved better *Success Rate*. The Pearson correlation coefficient indicated that the more diverse questions the students tried, the higher success rate they obtained (r=0.707, $p<.01$). Similarly, the more diverse examples the students explored, the higher success rate they obtained (*r*=0.538, *p*<.01). We also looked at the value of repeated access to questions, examples and lines. We discovered that the more often the students repeated the same questions and the more often the students repeated studying the same lines the higher success rate they obtained (*r*=0.654, *p*<.01; *r*=0.528, *p*<.01).

4.3 Evidence of Social Guidance

To obtain a deeper understanding of the open social student modeling as a navigation support mechanism, we plot all the students' interactions with Progressor^{+} (Figure 2). We categorized the students into two groups based on their pre-test scores (ranging from a minimum 0 to a maximum 20). Due to the pre-test scores being positively skewed, we split the two groups by setting the threshold at score 7. Strong students scored 7 points or higher (7~13) and weak students scored less than 7 (0~6). We color-coded the activities into two colors, orange and blue. Orange dots represent the activities generated by strong students and blue ones are the weak ones. The time of the action is marked on the X-axis and the question complexity on the Y-axis from easy to complex. We found 4 interesting zones within this plot. Zone "A" contains the current activity that students performed along the lecture stream of the course. Students had been working with the system very consistently throughout the first ten weeks. Zone "B" represents the region of after the tenth week. Zone "C" contains all of the attempts to explore earlier content, which the system motivated students to do to achieve mastery of the subject. Zone "D" contains the attempts which students performed ahead of the course schedule. It is not surprising that a lot of the student interactions with Progressor^{+} occurred in Zone A. More interesting are Zones C & D. A substantial proportion of the interactions occurred in Zone C. This indicates that the students were self-motivated to go back to achieve better mastery on already introduced topics. Moreover, based on Zone D in the figure, we found that the strong students who already achieved mastery on the current topics were able to use the visual interface to explore topics ahead of the course schedule. In addition, the plot shows that strong students generally explored the content ahead of the weak ones. Such phenomena provided evidence that strong students worked on new topics in Progressor^{+} first and left the implicit traces for weak students that were visualized by the interface and provided proper guidance for weaker students. It also demonstrated that the system was actually inviting students to challenge themselves to move a little bit ahead of the course pace instead of passively progressing.

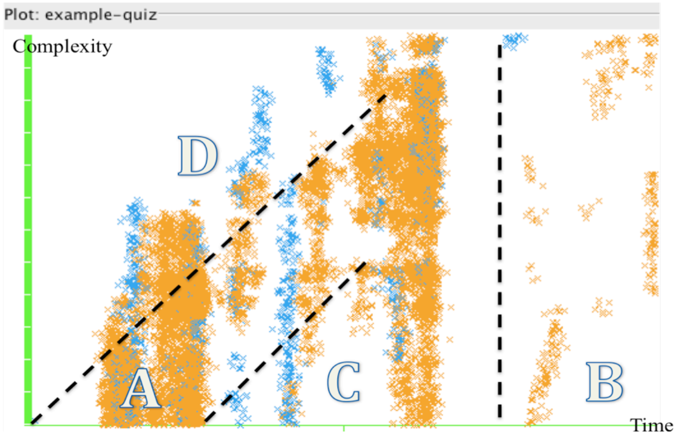

Fig. 2. Time distribution of all examples and questions attempts performed by the students through Progressor+. X axis is the Time; Y axis is the complexity of the course. Blue dots represent strong students' actions; orange ones are the weaker ones' actions. Zone "A" – *lecture stream*, zone "B" – *final exam cut (after week 10)*, zone "C" –*work with material from earlier lectures*, zone "D" –*navigating ahead*.

5 Summary

This paper described an innovative tabular interface, Progressor+, which was designed to help students to find the most relevant resources in a large collection of diverse educational content. The interface provides progress visualization and content access through open social student modeling paradigm. Students were able to navigate through all their peers' models and to perform comparisons from one to another. An exploratory study was conducted. We found that students used Progressor+ heavily, despite of the non-mandatory nature of the system. We also confirmed the motivational value of the social guidance provided by Progressor+. The results showed that the interface encouraged students to explore more topics, examples, lines and questions and motivated them to do some work ahead of the course schedule. The increased diversity helped to improve students' problem solving success. A deeper analysis of the social guidance mechanism revealed that the strong students successfully led the way in discovering the most relevant resources, and provided implicit trails that were harvested by the system and served to provide social guidance for the rest of the class. The study results also demonstrated that the social open student modeling increased student engagement to work with learning content. The students working with Progressor+ spent more time working with annotated examples and self-assessment questions, attempted more questions, and achieving higher success rate.

While the results in this study were encouraging, we believe that the current approach has not yet reached its full potential. For example, given that students were able to discover more topics and questions by following implicit trails from the stronger students, could we take a proactive role and recommend trails to weak students instead of letting them follow the trails by themselves? According to our past work, providing adaptive navigation support significantly increases the quality of student learning and student motivation to work with non-mandatory learning content. We plan to have a richer integration of open social student modeling with adaptive navigation support. Furthermore, we are motivated to investigate deeper the issues of data sharing and model comparisons in open social student modeling interfaces.

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