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The Impact of Social Performance Visualization on Students

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***Abstract*— Over the last 10 years two major research directions explored the benefits of visualizing student learning progress. One stream of research on learning performance visualization attempts to build a visual presentation of students' learning progress, targeting the needs of instructors and academic advisors. The other stream of research on Open Student Modeling (OSM) attempts to visualize the state of individual student's knowledge and present the visualization directly to the student. The results of the studies in that area show that, presenting students with basic representation of their knowledge will result in facilitating their metacognitive activities and promoting self-reflection and awareness. This paper tries to study the impact of a more sophisticated form of performance visualization on students. We believe that our visualization tool can positively influence students by granting them the opportunity to get a view of their performance in the content of the class progress. Moreover, we tried to boost their motivation by building a positive sense of competition using a representation of average class performance. In this paper we present study comparing two groups of students, one using the visualization and another without visualization. The results of the study shows that: 1) the students are likely to use the social visualization tool during the whole semester to monitor their progress in comparison with their peers; 2) the visualization tool encourages students to use the learning materials in a more continuous manner during the whole semester and 3) students will achieve a higher success rate in answering self-assessment quizzes.**

Keywords-component; Information Visualization, Open Student Modeling, Intelligent Tutoring Systems, Self-Assessment

I. INTRODUCTION

A. Background

Information Visualization is a field in Computer Science that examines techniques for representing a vast amount of abstract data, so that the data can be comprehended and interpreted by people. The main goals of visualization can be divided into three categories: exploration (searching for relationships, trends, and interesting phenomena); confirmation (validating or refuting hypotheses); and presentation (conveying information to others) [1]. Several researchers used visualization techniques to provide more effective learning and instructions. However, while these visualization tools could be valuable for both instructors and students, the majority of research in that area targets instructors and educational institutions [2-5] and only a minor fraction of projects focuses on providing visualization for students [6-9].

On the other side, Intelligent Tutoring Systems and Adaptive Educational Hypermedia have a built-in component of student modeling that maintains a representation of student knowledge based on the detailed monitoring of the students' behavior within the system. Traditional student models were hidden from students and used by the system to adapt its behavior to individual users. However, recent studies in student modeling argued in favor of Open Student Models (i.e. models that visually display details of student's learning status, such as their knowledge, difficulties, misconceptions, etc.). Bull and Kay [10] pointed out the key purpose of presenting the model to students is to support metacognitive activities such as reflection, planning, and self-assessment by providing feedback with respect to students' learning and knowledge. Moreover, it is possible to extend the student model with information about their peers. This type of model is called Open Social Student Model [11] and benefits from both metacognitive and social aspects of learning. Our visualization tool can be considered as an Open Social Student Model because it represents the student model along side with a replica based on class average.

B. The problem.

According to the information provided in the website of Next Generation Learning Initiative [12], only 42% of young people who enroll in college complete a bachelor degree and just 12% complete an associate degree. On the other side of the story, by the year 2018, 63% of all U.S. jobs will require some sort of postsecondary education. We believe that this would be the case for other countries too to and this fact demonstrates the importance of engaging college students in learning. Our study shows that providing students with social performance visualization could improve their engagement in learning and positively impact their performance.

C. Proposed Solution

Based on the theory of social comparison, motivational visualizations can be used to encourage user participation in online communities. In this paper we present the results of using a visualization tool on students' engagement in online learning activities. This visualization tool exploits the actual web usage data of students in a learning support portal (KnowledgeTree) for C programming. KnowledgeTree [13] is an adaptive repository of distributed learning resources that enables instructors to present the learning material from different sources in a hierarchy of course objectives. These resources include lecture slides, program examples, teacher comments, self-assessment quizzes, etc. The portal carefully

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stores all the activities of students and provides a fruitful resource for our student modeling engine. In this research we compare the usage pattern of learning resources available in the learning portal between two groups of students. The first group had access to a basic form of social navigation support while the other group used an explicit form of social visualization (in the form of Gauge, BarChart, TreeMap) to view their progress and compare their selves with class average.

The paper is structured as follows. Next section presents a brief overview of open user modeling and the use of visualization tools to support students learning (Section 2). The specification of our social visualization toolis presented in Section 3. Section 4 covers the study design and results. In Section 5, we discuss our findings based on the results and we present an evaluation about the validity of our findings. Section 6 provides conclusion and future work.

II. Literature Review

One of the earliest attempts on providing visualization tools to identify risky students and devise the way of supporting their learning has been done by Mazza and Dimitrova [14]. CourseVis is a visualization tool that helps instructors to identify problems of students early on in the semester. However, as we mentioned in introduction, our research is focused on providing students with visualization tools, which fits into the category of Open Student Modeling.

There are two main streams of work on open student models. One stream focuses on visualizing the model to support 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 [15]. Representations of the student model 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 the developing knowledge, difficulties and the learning process, and students' engagement, motivation, and knowledge reflection [15-17]. Dimitrova et al. [18] explore interactive open student modeling by engaging students to negotiate with the system during the modeling process. Chen et al. [19] investigated active open student models in order to motivate them to improve their academic performance. In our own research group work on the QuizGuide system [20] we embedded open learning models into adaptive link annotation and demonstrated that this arrangement can remarkably increase student motivation to work with non-mandatory educational content.

To support social learning, it is common to show learners average values of the group model, e.g., average knowledge status of the group in a given topic. These models fall into the category of group based student models. Both individual and group based open student models were studied and demonstrated the increase of reflection and helpful interactions among teammates. Bull & Kay [10] described a framework to apply open user models in adaptive learning environments and provided many in-depth examples. Open group modeling enables students to compare and understand their own states among their peers. Moreover, such group models have been used to support collaboration between learners among the same group, and to foster competition in a group of learners [21]. Vassileva and Sun investigated the role of social visualizations in online communities. They summarized that this kind of visualization increases social interaction among students, encourage positive competition, and provide students the opportunity to build trust in others and in the group. Bull and Britland [22] used OLMlets to investigate the facilitation problem for group collaboration and competition. The results showed that optionally releasing the models to peers increases the discussion among students and encourages them to start working sooner.

III. Methodology

To investigate the impact of social performance visualization on students' performance, we developed a social visualization tool KnowVis and deployed it in the context of a C programming course. The visualization tool was developed using GVIS framework [23]. KnowVis was accessible to students through the course portal, KnowledgeTree [13], which also provided access to a range of interactive learning resources delivered by *activity servers* QuizGuide [20], WebEx [24] and NavEx [25]. QuizGuide provides the adaptive navigation support for self-assessment quizzes, WebEx supports learning from annotated examples, and NavEx provides the adaptive navigation for annotated examples. KnowVis gathers student data by retrieving all the student usage and performance logs maintained by the activity servers. After extracting the learning activities from the activity servers, KnowVis calculates the confirmed knowledge of the individual and the group based on their answers to the self-assessment quizzes.

To respect the principles of abstraction and progressive evaluation, the tool offers two levels. The first set of visualizations in KnowVis contains two gauges to indicate the student's attempts and confirmed knowledge (Upper part of Fig. 1). The *attempts* variable measures the total number of access to the learning objects by the student. The *confirmed knowledge* summarizes the student's current knowledge based on answering self-assessment quizzes. These two succinct indices not only represent the students' current performance in the course, but also point out where they are standing in contrast to the entire class. Each index indicated on the gauge can be drilled through by two other different visualizations, BarCharts (Lower part of Fig. 1) and TreeMaps (Fig. 2). For example, once the BarCharts Attempts is selected, each detail learning activity will be presented with the actual value as a bar. To give the students the opportunity to quickly locate their deficiencies and reflect on them, KnowVis also presents them with two side-by-side TreeMaps, one representing the performance of individual student in the class and the other presenting the average performance of class. These detail views provide the opportunities for students to closely monitor their learning progress in a more fine-grained granularity and comparing it with the class average.

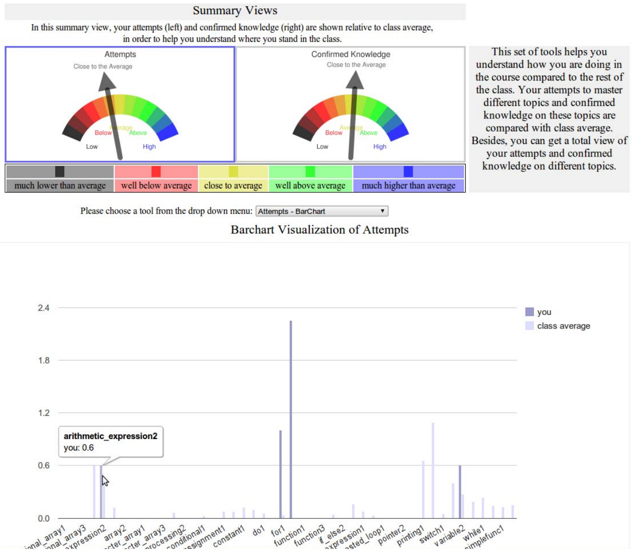

Figure 1. Student View of KnowVis

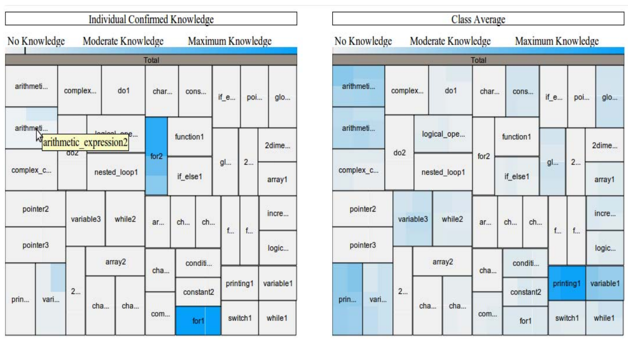

Figure 2. TreeMap Visualization of Attempts

IV. Evaluation

To evaluate our visualization tool, we conducted a thorough evaluation in a semester-long classroom study. The study was performed in an undergraduate Introduction to C Programming course, offered by the Community College of Allegheny County in the Spring Semester of 2011. To assess the impact of our visualization tool, we compared the student usage data with another comparable class taught by the same instructor, same course structure and same personalized learning platform only without the visualization tools. This group used the same learning resources only without the visualization in the Fall Semester of 2010. All students had access to the same learning activity servers (QuizGuide, WebEx, and NavEx) through the KnowledgeTree course portal. All student activities within the system were recorded, including every student attempt to answer a question, read an example, study a line of the codes, etc. The system also stored a timestamp, the user's name, session ids, and the results of answering the self-assessment quizzes (right or wrong).

A. Basic Statistics

We expected that providing the students with social performance visualization would increase students' awareness of how they are doing in comparison to their peers and cause them to be more engaged in online learning activities. The main finding about this study was that, the percentage of students that tried self-assessment quizzes got almost doubled increasing from 47% to 78%. We also found that the overall number of activities they performed within the system increased during the whole semester and the students were more engaged to use the system. Table I shows the overall statistics about application usage within the system.

The reason why we separated the QuizGuide from other applications in this table is that, there is an interesting pattern regarding to the student's behavior in self-assessment quizzes (record highlighted in the table). As we can see in Table I, the average number of attempt to answer the self-assessment quizzes is decreased for the students using visualization. We tried to investigate this more deeply so we calculated average time the students spent on quizzes and their success rate. The overall statistics about the student performance in QuizGuide is summarized in Table II.

TABLE I. Overall Statistics of Application Usage

		Without Visualization	**With Visualization**
		Fall 2010	***Spring 2011***
QuizGuide	#Users	7 out of 17 (41%)	15 out of 19 (78%)
	#Attempts	2347	2804
	Average	335.28	186.93
Other Apps	#Users	17	19
	#Records	9921	16081
	Average	583.59	846.37

TABLE II. Overall Statistics of Application Usage

	Without Visualization	**With Visualization**
	Fall 2010	***Spring 2011***
Total # Attempts	2347	2804
Total # Questions	179	179
Average # Sessions	4.6	4.42
Average Time Spent	3013	2728.18
Average # Attempts	335.28	186.93
Average # Success	127	88.66
Average Success Rate	39%	48%
Std. Dev. Success Rate	0.089	0.13

The data showed that the average amount of time spent on self-assessment quizzes for each user increased by 20%. More importantly, the average success rate (number of correct answers divided by number of attempts) also increased by 9%. We can consider these results as a sign that the students paid more attention and were more serious when they approached the system and they spent more quality time in solving the problems because they know that it directly affect their progress visualization. We can also assume that the social visualization tool not only made them spend more time in the system but also created a sense of competition between them that resulted in more accuracy. The results of our study show that the students are likely to review their confirmed knowledge level provided by the system and perceive a sense of comparing their progress with their peers. As we presented in the introduction, this could be explained by the theory of social comparison.

We also investigated the number of sessions the students accessed the systems and the average time they spend in each session. The average number of session was increased from 8.87 to 11.71 and average time spent by students within the system was almost doubled, going up from 1679.84 seconds to 3314.41 seconds.

B. Deeper Analysis

Although there were improvements in system usage by the students, the basic statistic results did not show any significant improvement. Consequently, we tried to analyze the student data more deeply considering they usage pattern during the whole semester. The system was introduced to both groups of students in the beginning of the semester and both of them had accessed to the system during the whole semester. The Fall 2010 group (without visualization) accessed the system in a 94 days period and had one midterm exam on day 45. The Spring 2011 group (with visualization) accessed the system in a 92 days period and had one midtermexam on day 44. We tried to investigate the daily behavior of students during the semester. Each semester consists of 14 weeks. Fig. 3 shows the number of records for both groups in a weekly manner.

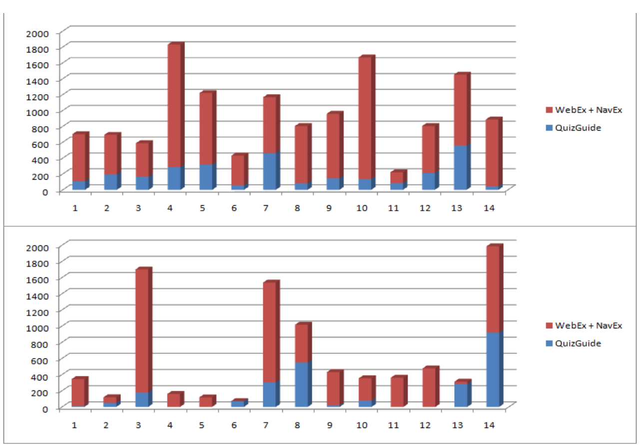

Figure 3. Weekly Distribution of Activities (Top with Visualization and Bottom without Visualization)

Table III shows the results of the investigation. As it is shown by the data in the table, using visualization also improved the daily activities of students but not in a significant way. Looking at Fig. 3, we noticed that there is a sudden increase among the usage data of students in the group without visualization (graph in the lower part) after midterm. This caused us to look at the students' usage data before the midterm and we found some significant increase among student usage data before the midterm exam. Table IV shows a brief summary of the results.

As we can see in the table, the daily usage of the system within the first part of the semester (before midterm) was significantly improved in all levels for the group that used visualization. This result could be interpreted as the early installment of the social performance visualization encourages consistent efforts particularly early on in the semester, which is really important because in that period they have enough time to reflect on their weaknesses and keep up with their course load as quickly as possible. Therefore, the students were better prepared during the whole semester, and in fact this hard work resulted in a higher success rate in answering the self-assessment quizzes.

TABLE III. DAILY USAGE REPORT (WHOLE SEMESTER)

Daily Usage Report	**Without Visualization**	**With Visualization**
	Fall 2010	***Spring 2011***
Sum. # Attempts	12280	18887
Avg. # Attempts	129.26	198.81
p value	0.07 > 0.05 (not significant)	
Sum. # Sessions	167	217
Avg. # Sessions	1.76	2.28
p value	0.09> 0.05 (not significant)	
Avg. # Users	1.17	1.60
p value	0.014< 0.05 (significant)	

TABLE IV. DAILY USAGE REPORT (BEFORE MIDTERM)

Daily Usage Report	**Without Visualization**	**With Visualization**
	Fall 2010	***Spring 2011***
Sum. # Attempts	2091	7925
Avg. # Attempts	53.62	203.21
p value	0.0006< 0.05 (significant)	
Sum. # Sessions	75.00	130.00
Avg. # Sessions	1.92	3.33
p value	0.007< 0.05 (significant)	
Avg. # Users	1.23	2.03
p value	0.0017< 0.05 (significant)	

V. CONCLUSION AND FUTURE WORK

In this paper we explored the potential of presenting the students with a social visualization of their performance. We compared the online learning behavior of two groups of students in two different semesters in the same course with the same instructor. We showed that the students using visualization were more engaged in learning activities and also had better performance in self-assessment quizzes. It means the students were more conscious and serious when they presented with a visual representation of their performance. We also showed that the students in second group made more consistent efforts throughout the semester, especially in the beginning of the semester.

We believe that the lack of significant differences on the commonly acceptable level of $p < 0.05$ was caused by a relatively low number of students participated in the study. We plan additional studies engaging larger number of students. We also plan to extend the capabilities of the system by adding more social aspects to the system other than just the average information about the class. We also plan to focus on providing social visualization interfaces for popular and widely used online learning environment such as Moodle (which was already applied for a test case) to enable educational institutes benefit from our visualization component.

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