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ARTICLE

Evaluating a Persuasive Intervention for Engagement in a Large University Class

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Abstract

Persuasive Technologies (PT) are computational methods, strategies, and design techniques, grounded in social psychology to change user attitudes/behaviours. PTs have been applied in diverse areas, such as eCommerce, health, workplace, vehicles, urban and ambient environments. A kind of PT that has become popular in eLearning is known under the name "Gamification" – introducing game mechanics (such as points, levels, badges, leaderboards) into non-game environments. We implemented three persuasive strategies in an online learning environment supporting a University class to encourage more active engagement of students in their online learning activities. The paper presents a controlled study that shows a positive effect of the persuasive intervention on student engagement, measured by the increase in their online activities. The study results also show that personalizing the persuasive strategies to the receptiveness of individual students amplifies their effect on engagement.

Keywords Persuasive technology · Student engagement · Social influence strategies · Personalized learning support · Social comparison · Social learning · Competition

Jim Greer Deceased.

TRIBUTE

Writing this paper has been a great honour and responsibility. Fidelia was Jim's last graduate student (co-supervised with Julita, from 2017 until Jim's passing in June 2018); she defended her MSc Thesis in December 2018. Jim cared deeply about applying on a large scale the results of his research. Like with the I-Help project 20 years earlier (Greer et al., 1998), we embarked on this project to address a real problem in our university learning support system. While Jim served as the Director of the Teaching and Learning Center (TLC), he introduced many novel ideas and systems to support teaching and learning, especially targeting first-year classes with high student attrition. Our research aimed to explore if persuasive technology strategies can be used to engage students to participate in the learning activities provided by learning support technologies designed and implemented by Jim's IT team during his service as Director of the Teaching and Learning Center of the University. Our target course was the Introduction to Biology class – one of the largest classes on campus. There was no margin for bugs, errors, or possible undesirable effects on student engagement. Unfortunately, Jim did not live to see the analysis of the results; he participated constructively in every step of the research until the analysis of the results. Fidelia and Julita believe that he would have been delighted to see that the intervention was successful, our research questions were answered, and that our work resulted in three conference and workshop papers. Most of all, he would have been pleased to see that Fidelia, inspired by Jim's mentorship, courage, humanity, and sense of humour, not only successfully defended her M.Sc. thesis but was awarded Vanier – the most prestigious Canadian Ph.D. scholarship, and is currently pursuing her Ph.D. in the area of AI in Education.

Introduction

Learning Support Systems (LSSs) are online systems such as Learning Management Systems (LMSs) designed to promote students' learning in blended and online education. LSSs complement classroom teaching with online materials, examples, tutorials, exercises, assignments, and quizzes. The increasing use of LSSs in higher education to enhance the learning experience and performance of students has created the need for these systems to be critically examined. Though LSSs make learning materials easily accessible, research has shown that it is often challenging to motivate students to engage actively with them. To effectively use LSSs, students need to maintain high motivation for academic activities (Araque et al., 2009). Motivation is defined as "*the process where goal-directed activity is instigated and sustained*" (Schunk et al., 2008 (p. 4)). According to (Schunk, 1995), motivation can influence what students learn, how they learn, and when they choose to learn. Motivated students are more likely to engage actively in their learning activities, undertake challenging activities, apply deep learning approaches, demonstrate creativity, show improved persistence and performance in their learning (Schunk et al., 2008). Motivation has been linked to students' cognitive and affective processes to show the relationship between students and the learning environment (Brophy, 2010). Thus, the learning process is deeply dependent on the context in which it happens and is shaped by the student's interaction and engagement with the environment (Nolan et al., 2011).

This paper presents an approach to increase student engagement in their learning activities within a LSS using Persuasive Technology in the context of a University course within a blended learning environment (a combination of face-to-face teaching with web-based learning). Persuasive Technology (PT) refers to digital platforms that use persuasive strategies in their design, which influence and motivate users to take certain actions to achieve a specific goal without using deception or coercion (Fogg, 2003). PTs have been shown to engage users in performing specific tasks (Goh et al., 2012; Guadagno & Cialdini, 2010). We describe an approach that uses three socially-oriented strategies of PT in motivating students to engage actively in their learning activities. We use the term "socially-oriented strategies" to denote strategies used in the area of PT that are inspired by the social influence theory (Kelman, 1958), which describes an intentional or unintentional change in an individual's opinion, action, and attitude due to the influence of other people (Guadagno & Cialdini, 2010). Socially-oriented strategies are included in the main existing taxonomies of persuasive strategies under different names. For example, (Cialdini, 1984) uses the term "social proof" for one of his six principles of influence based on the observation that people generally look to other people similar to themselves when making decisions. The Persuasive Systems Design Model (Oinas-Kukkonen & Harjumaa, 2009) presents a classification of 28 PT design principles and techniques, in which the category "social support" lists seven strategies: social learning (allowing the user to observe the target behaviour performed by others), social comparison (allowing the user to compare their performance with that of others), competition (leveraging human's natural drive to compete with others), cooperation (leveraging human's natural drive to cooperate), normative influence (leveraging social norms by peer pressure), social facilitation (providing means for discerning when others are engaging in the target behaviour at the same time), and recognition (providing public recognition for engaging in the behaviour).

Three of the strategies – social learning, social comparison, and competition – are commonly used in PT and have been shown to be successful in encouraging users in their performance of a specific task (Stibe & Oinas-Kukkonen, 2014). For this reason, we chose to implement these three strategies in a LSS.

Adaptive/Personalized online learning systems make learning easier and more effective for learners by providing learning environments that react to learners' characteristics, needs, and states (Brusilovsky & Peylo, 2003). Learners are motivated by different things, and PT systems can become more effective if they are personalized. Personalization can also eliminate the possible demotivational effects that some persuasive strategies may have for certain users (Kaptein et al., 2015; Orji et al., 2014). However, until now there has not been much work on the personalization of persuasive strategies in the context of LSS. Our research aims to fill this gap by exploring the effect of tailoring the three chosen socially-oriented persuasive strategies to individual students, depending on their susceptibility to these strategies. More specifically, our work investigates whether the social learning, upward social comparison, and competition strategies of PT incorporated into a LSS effectively encourage students to increase their engagement in their learning activities.

The research aimed to answer the following broadly formulated research questions:

- *How can socially-oriented strategies of PT be incorporated in a LSS to motivate students to increase their engagement in learning activities?*
- *Does personalization/tailoring of the persuasive strategy to the individual student amplify the persuasive effect on the student engagement in learning activities*?

We carried out a controlled field experiment during one semester in a large introductory biology class to find if the incorporation of three socially-oriented strategies into a LSS (in the experimental group) leads to an increase in student engagement in comparison to the control. We evaluated the effect of personalization by comparing tailored versus randomly assigned persuasive strategies. Student engagement in their learning activities was measured using interaction data - time-stamped logs of their activities in the learning system.

The paper is organized as follows: section 2 introduces Jim's previous work that motivated our project; section 3 presents the research process, method, and tools; section 4 presents the implementation of the experiment; and section 5 – the results. Section 6 presents a discussion of the results, and section 7 concludes the paper.

Background and Related Work

There is a lot of exciting research over the last 30 years, deploying AI techniques to support learners in various domains in their knowledge and skills acquisitions.

Persuasive Technologies

The effectiveness of PTs in changing behaviour and motivating people to achieve specific goals has been established in various domains such as health (Orji et al., 2014), e-commerce (Adaji et al., 2018), energy conservation (Gustafsson et al., 2009),

physical activity (Oyibo et al., 2019), and education (Alvarez et al., 2017). Previous research shows that PT could be successfully employed in influencing people to pursue higher education (Toor, 2016), self-regulated learning (Goh et al., 2012), and by designing persuasive learning objects with inherently persuasive concepts embedded (Behringer et al., 2013) in a broad range of domains. Christy and Fox (2014) showed that using the social comparison persuasive strategy could influence women's academic performance in maths in a virtual classroom. Aris et al. (2013) employed persuasive features in the design of mathematics courseware to encourage students in mathematics learning. The researchers reveal that persuasion can assist students in overcoming their negative attitudes towards mathematics. Lucero et al. (2006) demonstrated that integrating persuasive principles such as similarity, credibility, tailoring, and Gardner's Multiple Intelligence theory (Gardner, 1997) into educational software improved children's motivation to read and write. Furthermore, research reviewed studies that applied PT in education and highlighted its potential to provide interesting opportunities in teaching and learning that will motivate students to acquire new knowledge or skills (Devincenzi et al., 2017). Designing persuasive educational systems has received attention in research, however, studies that explored the effect of personalization of persuasive strategies in online educational systems are relatively limited both in number and scope.

Applying PT to engage students in learning activities is a feasible and promising approach because there is a rich palette of persuasive strategies, which have shown to be effective in engaging users in target behaviours in many domains, including education. Many of these strategies are not hard to implement because they are mostly domain neutral. In a blended learning context, the students are members of groups (classes, cohorts), making a particular class of persuasive strategies, called "socially-oriented strategies," particularly suitable.

Socially-Oriented Persuasive Strategies

The term "**socially-oriented strategies**" describes a class of persuasive strategies that provoke an intentional or unintentional change in an individual attitude or behaviour due to the influence of other people. Their effect can be explained by the Social Learning Theory (Bandura, 1971). These PT strategies change an individual opinion or attitude by using other people who are performing the desired behaviour as a role model for the target behaviour change. An essential element of socially-oriented strategies is to improve the performance of a specific task through reporting users' progress in a meaningful way that will encourage all users to progress. Recent research in the area of PT has shown that socially-oriented strategies are effective at encouraging users to accomplish desired goals (Foster et al., 2010; Stibe & Oinas-Kukkonen, 2014).

The strategies we examined include upward *social comparison*, *social learning*, and *competition*. According to the *social comparison* theory (Festinger, 1954), people use upward social comparison for self-improvement as they compare themselves to similar others who are performing well (better than them) on the specified task. Previous research in education reveals that students are often inclined to upward social comparison when comparing their performance (Buunk et al., 2005; Dijkstra et al., 2008). In the *social learning strategy*, there is no obvious comparison or competition. The user learns through observation, imitation, and modelling the behaviour of others (McLeod,

2011). *Competition* is a strategy that allows users to compare their behaviour metrics with those of others and encourages users to obtain the top measures by offering some reward (intrinsic reward in terms of self-efficacy and social reward in terms of reputation). Typically, competition is implemented as a leaderboard, where a user can see their position relative to that of their peers. The competition encourages users to accomplish a specific goal by tapping into the natural human drive to compete.

Personalizing Persuasive Strategies

Research has shown that individual differences exist in people's susceptibility to PT strategies (Kaptein et al., 2009). These differences could have an unintended effect on users of persuasive systems that use a "one-size-fits-all" approach. Hence, persuasive systems should be personalized to users' strategy preferences to improve their efficiency. Personalization means delivering PTs designed with the strategies to which the user is most receptive. It acknowledges that users react differently to several persuasive strategies, and the reactions affect the effectiveness of persuasive systems in motivating the users. Several studies (Orji et al., 2018) have shown that personalizing PTs to users is more effective in achieving behaviour or attitude change than a "one-size-fits-all" approach.

Therefore, we decided to explore if personalizing the social influence strategies to the students according to their receptiveness to a particular type of strategy (measured in advance using a validated tool) would amplify the effect of the strategy for the individual.

Social Visualization and Open Learner Modelling

The design of socially-oriented strategies requires devising some ways of informing the user of the actions of other users, i.e. making the community/group visible so that the user can compare themselves with, align with, or compete with others. Social visualizations provide a good way to achieve these functions. The term "social visualization" is used in social computing to denote a visual representation of certain aspects of the behaviour of a group of people with a specific purpose – to create awareness, create and enforce social norms. Social visualizations have been used in the area of AI in Education, e.g. (Bakalov et al., 2010; Hsiao & Brusilovsky, 2012) to increase student awareness of the activities of their classmates in different course sections and allow social comparison. Many studies have shown the efficacy of social visualizations at motivating people to increase their participation activities and contributions. For instance, (Sun & Vassileva, 2006; Webster & Vassileva, 2006; Farzan & Brusilovsky, 2008; Vassileva, 2008; Vassileva & Sun, 2008) established that social visualization of users in an online learning community which gives students opportunity to view and compare the activities of each other resulted in increased participation and contributions. Also, (Valkanova et al., 2013) investigated the use of visualization to increase attention to a subject. They demonstrated that the display of visualization in public places led to increased social awareness. Their visualization compares individual's and community energy consumption and provides an opportunity for people to send their responses.

Social visualization can also be considered as an open group learner model. Starting with (Bull, 2004; Kay, 1997), this trend explored how "opening learner models" by making them visible and manipulable by learners can help engage the learner in a dialogue (Dimitrova et al., 2001), improve the accuracy of the system model of the learner (Zapata-Rivera & Greer, 2000) and also trigger reflection in the learner (Bull & Kay, 2007) which can be both motivating and showing them areas they need to focus on. Scaling the open learner model to a group model with appropriate visualization, as in (Bakalov et al., 2010; Hsiao & Brusilovsky, 2012), has shown that social visualizations are able to motivate students to engage in desirable learning activities and reflect on their learning (Somyürek et al., 2020).

We implemented the three selected socially-oriented strategies of persuasive technology as social visualizations. The persuasive strategy defines what information is visualized, e.g. whether the student can see just the score of the group (social learning) or also their own score to easily compare it with that of the group (social comparison) and or with specific peers (competition).

Personalized Learning Technologies in Higher Education: SARA

In university teaching, the most commonly applied technologies are LMSs, such as Moodle, Blackboard, Canvass, and course support systems (CSSs) provided by textbook publishers, allowing students to practice the textbook material using interactive exercises and quizzes. These systems provide an opportunity to harvest learning analytics data in providing personalized general mentoring advice, e.g. (Piotrkowicz et al. 2021; Mousavi et al 2021).

A system called SARA (Student Advice Recommender Agent), which provides personalized advice, was developed under Jim Greer's leadership (Greer et al., 2015; Mousavi et al. 2021). It directs the student to appropriate learning supports and resources by mining data from student academic history, personal history (including demographics), and current activity (progress in a course and other related activity pertinent to academic success). SARA uses a predictive model of student academic success in specific courses. It was introduced in "Introduction to Biology" – the largest blended undergraduate course at our University, which uses BlackBoard Learn (BBL) and online MindTap (an online system provided by the textbook publisher containing the electronic textbook along with additional interactive materials, e.g., exercises, and quizzes). Based on the SARA prediction models, the weekly SARA messages were personalized for stereotypical students with certain attributes. SARA's predictive model performed very well (Mousavi et al. 2021). The students who regularly read the weekly advice scored significantly higher – by 4.6 percentage points – than the predicted score after the midterm exam. In contrast, students who did not read SARA's advice scored very near the predicted grade (Greer et al., 2015).

The findings from SARA's evaluation inspired our project. The evaluation found that the key problem was keeping learners' focus on accomplishing the specified objectives without instructors monitoring them. Engaging students in online learning activities can be difficult. Applying PT strategies to help students maintain their engagement, i.e. to stay on task, pay attention to the SARA messages, and participate more actively in the learning activities provided by the LSS, could improve their performance.

Student Engagement and Gamification in Education

The term "Student engagement" as used in this paper refers to the participation of students in the learning process and related activities. Several studies revealed that student engagement is an important factor that affects student achievement. For instance, research showed that students' active involvement in learning process correlates positively with increased student achievement (Astin, 1999). Student engagement is essential for deep and effective learning – the more students' study and practise a concept, the more their mastery skills and ability to implement the concept in the real world improve. Various tools such as surveys of student experience and self-report of their learning, and objective measures have been used in assessing student engagement. Lee (2014) through multilevel analysis of U.S data for International Student Assessment 2000 showed that student engagement significantly predicted reading performance. Carini et al. (2006) used the National Survey for Student Engagement (NSSE) and reported a positive relationship between NSSE results and academic performance of students.

Student engagement has also been determined using objective measures. Sabourin et al. (2013) used students' off-task behaviour obtained from learning interaction data to identify their disengagement using a dynamic Bayesian network. The researchers discovered that off-task behaviour correlates with decreased student learning. Moreover, Hussain et al. (2018) assessed the effect of student engagement on learning performance using the highest educational level, assessment scores, final results, and the number of clicks on virtual learning environment activities as input to machine learning algorithms. The algorithms build models which predicted the engagement level of students in different activities as output variables.

Furthermore, through a meta-analysis of 69 independent studies on student engagement, Lei et al. (2018) revealed a moderately strong and positive correlation between student engagement and academic performance. Thus, analyzing learning systems data helps to determine the students' actual learning behaviours and to provide reports on their learning progress which can help educators in their decision-making process.

Gamification in Education

Gamification means using game elements and techniques in non-game application contexts (Deterding et al., 2011). These game elements are usually implemented in the form of points, badges, levels, challenges, rewards, and leaderboards (Zichermann & Linder, 2010). Research has established that gamified systems and services increase people's participation, engagement, loyalty and competition (Zichermann & Linder, 2010). As a result, several domains employ game elements in their system design to achieve a specific goal. The application of gamification in the education domain is not new. Several studies that focus on the use of gamification concepts to motivate students learning engagement in higher institutions exist. For instance, Charles et al. (2011) established that a gamified system used in a programming course for undergraduate students increased students' engagement and improved performance in examinations and coursework. Dominguez et al. (2013) investigated the use of gamification to improve the engagement and motivation of students. They established that students who used the gamified system performed better in the practical assignment and scored

higher generally than those students that did not experience the gamified system. Equally, Barata et al. (2013) implemented gamification in a college course using points, challenges, levels, leaderboards, and badges. They measured the impact of gamification on the learning experience by comparing data from the gamified and non-gamified systems. Their results reveal that the gamified system resulted in improved attention, participation, and performance of students.

Research Process, Method, and Tools

To answer the research questions defined in the Introduction section, we developed three visualizations implementing the three socially-oriented strategies. We used a survey to discover students' susceptibility to the three strategies and designed a controlled experiment. This section presents the methodology including the timing of the intervention, the metrics, the assignment of participants into different groups and the selection of validated tools (surveys) to evaluate the students' perception of the impact of the persuasive intervention. Our research followed a process illustrated in Fig. 1.

Design and Implementation of the PT Strategies

Persuasive design techniques (Oinas-Kukkonen & Harjumaa, 2009) were applied in implementing the three socially-oriented PT strategies (upward social comparison, social learning, and competition) using visualizations showing the students' assessment grades. The three strategies were implemented as three versions of social visualization presented in Fig. 2a, b, and c.

Figure 2a shows the social comparison strategy implemented as a visualization that shows the class average for each assessment and the grades of five random students

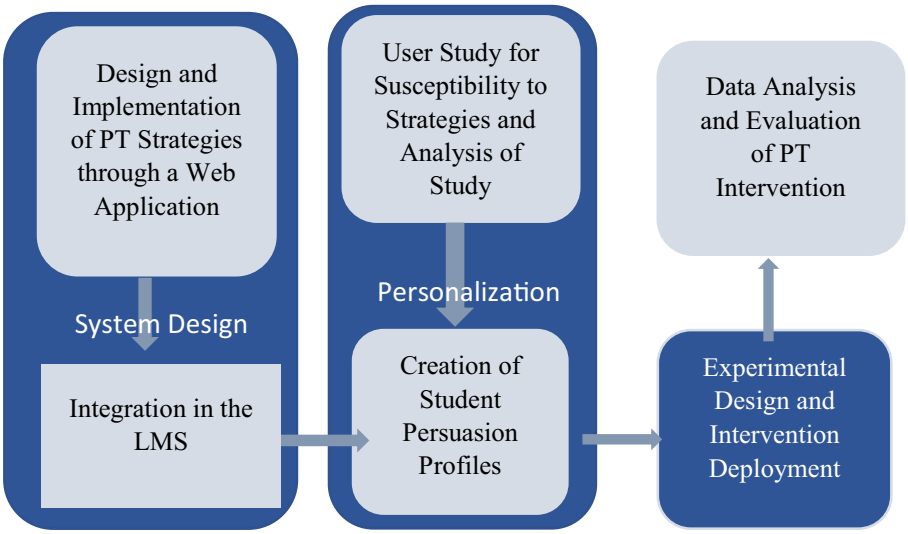
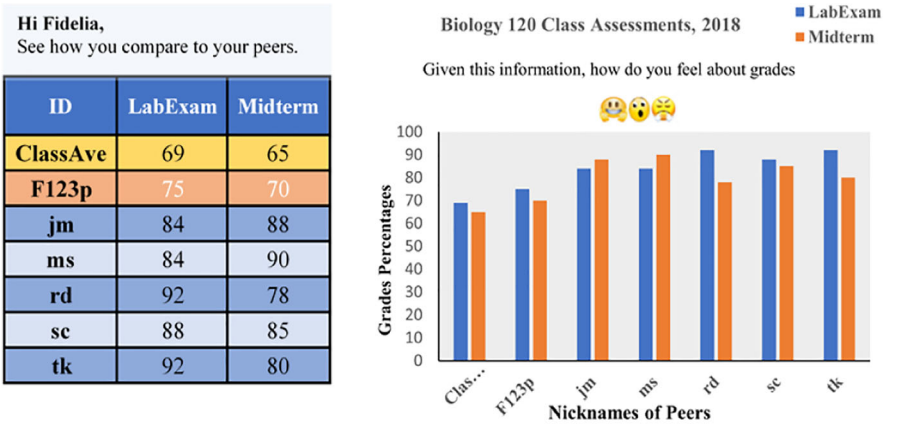
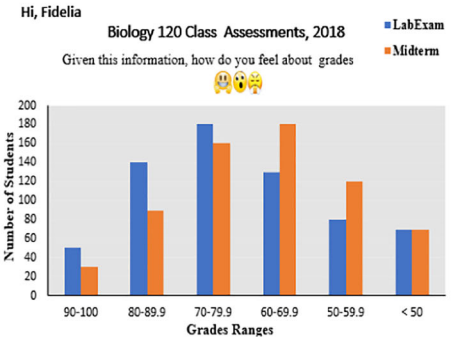


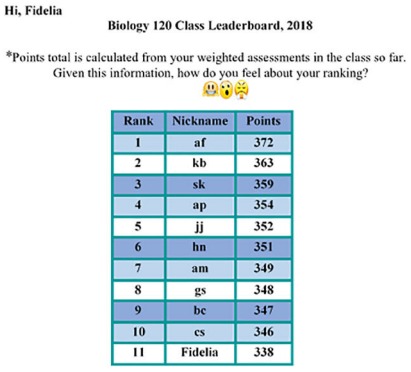
Fig. 1 Block diagram of the research process



a) *Social Comparison Strategy*



b) *Social Learning*



c) *Competition*

Fig. 2 Social visualizations implementing the three socially-oriented strategies. (**a**) *Social Comparison Strategy*, (**b**) *Social Learning*, (**c**) *Competition*

who have higher grades than the viewer, to make the student aware of her performance relative to others who are performing well in a particular course and motivate her towards the desired learning outcome. Figure 2b shows the visualization implementing social learning. It presents grade ranges for each assessment and the number of students within each grade range to provide students with opportunities to learn from the overview of everyone's performance. Social learning is enabled in this view through the display of grade distribution of course assessments to motivate students to seek to improve their success in their assessments which consequently motivates them to engage in more learning activities. Figure 2c presents the visualization for the Competition strategy. Students are rewarded with points based on their performance on the assessments. For a student to gain more points and change her position on the leaderboard, she must improve her performance in the next assessment. The visualizations are updated dynamically when students perform new assessments. Each visualization provides students with an opportunity to provide feedback on their feeling when viewing the visualization, using three emojis: satisfied, surprised, and frustrated. The

persuasive system design and integration are not the focus of this paper as they have been reported in (Orji et al., 2019; Orji et al., 2018).

We acknowledge the subtle difference in the semantics of the term "social learning" in the area of psychology and persuasive technology. The three strategies – social comparison, social learning, and competition –are defined in the persuasive design principles (PSD) taxonomy by (Oinas-Kukkonen & Harjumaa, 2009). They are classified as different strategies.

The social learning strategy as defined in Bandura's social learning theory suggests that learning could occur through observation, imitation, and modelling of behaviours of others. In persuasive technology, the implementation of the strategies is guided by pragmatic considerations of what is possible and practical. Many studies, such as (Stibe & Oinas-Kukkonen, 2014) followed the PSD principles and implemented the strategies in a way that makes sense in the application domain. The implementation of the Social Learning strategy often involves informing the user about the general progress of other users in a target behaviour (not observing the actual behaviour) but without facilitating comparison or competition. In our case it was not possible to make observable the behaviour of others directly (due to the asynchronous nature of the online activities and privacy considerations), so we chose to implement the strategy in a visualization that allows students to observe the aggregated performance of other students.

Personalization to Students' Susceptibility to the Three Socially-Oriented Strategies

To answer the second research question defined in the introduction, we had to create persuasive profiles for the students. We conducted a study on students' receptiveness to persuasion using a validated tool called "persuadability inventory" (Busch et al., 2013) to determine to what extent each of the three socially-oriented strategies would effectively encourage individual students in their learning activities. We analyzed the data from the study and, based on the analysis, created *persuasion profiles* for each student. The personalization (tailoring) was implemented by selecting the visualization version corresponding to the most preferred strategy in the student's persuasion profile. The students were then grouped based on the experiment conditions as outlined in the next section. A more detailed report of the student profiling study can be found in (Orji et al., 2019).

Experimental Design

The participants in this study comprise of students that registered in Biology 120 in our university. This section describes the design of the controlled experiment, the tailoring of the three versions of the system to different groups of students based on their persuasion profile and predicted grades, and carrying out the actual experiment using their learning support system.

Privacy Concern

The visualizations access the assessment grades of individual students by using their student IDs. To provide personalization while protecting the students' privacy, we used a pseudonymized student ID to display students' grades and points. The visualization

viewer sees their real ID to easily identify how they are progressing in the course and compare it with others. Students whose data was used for analysis were asked to provide informed consent. The study was approved by the University's Research Behavioural Ethics Office.

Experiment Design

Based on the two research questions stated in the Introduction, our goals in the experiment were to evaluate:

1) The effect of a persuasive intervention (the visualizations based on all three persuasive strategies) on students' engagement in learning activities, and
2) The effect of personalizing/tailoring the persuasive strategies to students who participated in the pre-survey on the students' engagement.

To evaluate (1) we used both within-subject and between-subject design. In the within-subject design, we measured and compared the students' engagement for similar periods before and after introducing the persuasive intervention. We hypothesized that there would be an increase in the measured engagement when subjected to the intervention. To implement a between-subject design, we divided the participants into Experimental (Intervention) and Control groups. The students in the Experimental group had access to the intervention - a social visualization implementing one of the three persuasive strategies. In contrast, the students in the Control group did not have access to the visualization. We hypothesized that the students in the Experimental condition would be more engaged in learning activities than those in the Control condition.

To evaluate (2) we used a between-subject design. We divided the Experimental group into two sub-groups. In the "Tailored" group, the social visualization presented to each student corresponded to her persuasion profile. In the "Non-tailored" group, the visualization presented to the student was assigned randomly. Thus, the Tailored group comprised three sub-groups of students, who depending on their persuasion profiles, would see either the Social Learning, Social Comparison or Competition version of the visualization. We hypothesized that the students in the Tailored group will be more engaged than those in the Non-tailored group.

Assigning Students to the Different Groups

We exercised care in the formation of the Competition group since previous research indicates that competition-averse students exposed to a leaderboard may get discouraged and frustrated (Orji, 2017), especially if they are not doing well in the class. To avoid putting students who might be vulnerable in an experimental condition that may hurt their motivation, we decided to employ a game design technique called "game balancing" in assigning participants to the competition strategy. Game balancing is used in game design to make games enjoyable and motivating to all players. It is normally used in competitive games to enhance gamer's ability to achieve their desired objectives. For example, Adams et al. (2006) demonstrated that people would be motivated to participate in competitive activities if they have the opportunity to win.

Also, Cechanowicz et al. (2014), in their research with a competitive racing game, indicated that "*in competitive games where players' skill levels are mismatched, the play experience can be unsatisfying for both stronger and weaker players*." In addition, research (Brian P. Gatens n.d.; Cechanowicz et al., 2014; Newheiser n.d.) have shown that grouping people with equal strength and ability in competition make the game more enjoyable and desirable. The students' grades in the course predicted by SARA were employed to balance the ability of participants in the competition group.,

Kappen and Orji (2017) have shown that gamified elements and persuasive strategies can influence people to achieve the desired goal. To balance the ability of students grouped under competition in the tailored group, only those who have the highest susceptibility to competition strategy and have top grades (predicted grades 75% and above) were involved in this group. The students with the highest susceptibility to competition strategy but with predicted grades less than 75% were assigned to their second-most preferred strategy from their persuasion profile. Most of these students had social comparison as their second preference, which is not surprising since previous research (Orji et al., 2014) has established that susceptibility to competition and social comparison are correlated. The resulting grouping of students under the different conditions for the experiment is shown in Table 1.

The Control group comprised students who used a version of the learning system that did not have persuasive intervention incorporated. The Tailored group included students who would be using the three versions of the persuasive visualization: Competition group – students with a high susceptibility to *competition AND predicted grade > 75%*, Social Comparison group – students with the highest susceptibility to *social comparison*, and Social Learning group – students with the highest susceptibility to *social learning*. The "Non-tailored" group comprised students with an unknown persuasion profile (who did not participate in the receptiveness study) and those who did not show receptiveness to any of the three persuasive strategies. One exception to the random assignment in the Non-tailored group was that only students with high predicted grades (80% and above) were assigned a visualization implementing Competition.

Implementation of the Study

The setting for this research is the introductory Biology class (Biol 120) offered at our University during the winter term of 2018. The experimental intervention lasted 6 weeks, starting in the middle of the winter term, after the mid-term exam. The class had 690 registered students. Of these, 228 completed the system exit survey at the end of the study. Only the data from these 228 students were included in the data analysis. Among the 228 participants used in the analysis, 96 were in the Tailored group, 97 in the Non-tailored group, and 35 were in the Control group.

The students in the experimental group used a version of SARA that included persuasive social visualizations. In contrast, those in the control group used a version of SARA without social visualizations. MindTap is a commercial learning platform that offers an e-book, study tools, interactive exercises for practice, customizable quizzes, and multimedia learning tools. It organizes the topics for the course based on weeks. The persuasive visualization could not be integrated into the Mindtap; however, following (Brusilovsky et al., 2016), we expected that

Table 1 Summary of the assignment of the persuasive system to the different experimental condition of students

Control group $N = 35$	(SARA N = 35) (MindTap $N = 32$)			
Experimental group $N = 193$	Competition	Social comparison	Social learning	*Comments*
Tailored N = 96 (SARA $N = 96$)	$N = 15$	$N = 62$	N = 19	*Students with lower predicted grades assigned to the social comparison or social learning based on their second preference strategy*
(MindTap $N = 91$)	(Sara:15 MindTap: 14)	(Sara:62 MindTap: 59)	(Sara:19 MindTap:18)	
	Students with high score in Competition and predicted grades (over 75%).	Students with high score in Competition and predicted grades <75% and Social Comparison as their second high-score strategy	Students with high score in Competition and predicted grades <75%, and Social Learning as their second high-score strategy	
		The students with the highest score in Social Comparison	Students with the highest score in Social Learning	*The strategy to which the students showed highest response*
Non-Tailored N = 97 (SARA $N = 97$) (MindTap $N = 85$)	N = 6	$N = 43$	$N = 48$	*(1) Students who did not take part in the Pre-Study (unknown persuasion profiles)*
	(Sara:6 MindTap: 4)	(Sara:43 MindTap: 38)	(Sara:48 MindTap: 43)	
	Students with low scores in all strategies or unknown profile and high predicted grades (>80%)	Students with low score on all strategies or unknown persuasion profiles	Students with low score on the three strategies or with unknown persuasion profiles	*(2) Students who scored low on all three strategies*

placing the persuasive intervention into the general advice-giving system SARA would trigger reflection and inspire students to engage more in the learning activities provided by the MindTap system.

All students used SARA, so the numbers of students whose activities on SARA are reported in the analysis corresponds to the numbers stated above. For the analysis of student activities on MindTap, however, we had a smaller sample because 20 students out of the 228 did not sign up for online MindTap use. As a result, the MindTap analysis is based on 208 students, consisting of 91 in the tailored group, 85 in the non-tailored, and 32 in the control group. Table 1 shows the number of participants in each sub-group considered in the analysis of activity data in SARA and MindTap.

Data Analysis and Evaluation of PT Intervention

This stage of the experiment investigated the effectiveness of the persuasive visualizations at motivating students for active engagement in their learning support systems SARA and MindTap. The data log files from the two systems contained timestamped activities of each student's activities. Student engagement scores were calculated as weekly averages of students' activity counts. The engagement scores before introducing the intervention for each student acted as a baseline for our analysis.

The two systems allowed logging different activities of students; hence the measures of engagement in the systems were different. In SARA, the engagement was measured by the number of system view events and the number of hover/clicks on learning resources and the persuasive visualization. In MindTap, the engagement was measured in terms of the number of logins, time spent on the system, and engagement score (calculated based on time spent and activities completed). The effect of the persuasive visualizations on each student's engagement in learning activities was measured and aggregated for each experimental group to compare across the experimental and control conditions.

The first research question, as defined in the introduction: *"Can socially-oriented strategies of PT be incorporated in a LSS to motivate students to increase their engagement in learning activities and improve their academic performance?",* has two parts:

1) Demonstrating how PT can be incorporated in a LSS, and
2) Showing that it leads to an increase in engagement in learning activities.

Part (1) has been answered by describing the implementation of the socially-oriented persuasive strategies as social visualizations in section 3.1. Part (2) is answered by comparing the engagement of the Experimental group *before and after introducing the intervention* (the social visualizations as part of SARA), and also by *comparing the engagement of the Experimental and the Control group during the 6 weeks of the intervention*. Because the students engage with two different systems, SARA (providing advice, some learning resources, and the visualizations) and MindTap (the actual learning environment), *analysis of the activities in both systems was performed*.

The following methods for statistical analysis were used, as described in the next section:

- One-way within-subject ANOVA to compare engagement before the persuasive intervention and during the intervention.
- Repeated-measure ANOVA to compare the engagement in the Experimental and the Control group over time.
- Repeated-measure MANOVA (RM-MANOVA) with time (before and during the study) as a within-subject factor and the experimental condition that students were in (competition, social comparison, and social learning) as between-subject factor.
- Independent sample t-test to compare engagement between tailored and non-tailored (intervention type) in the SARA system.
- Repeated-Measure MANOVA (RM-MANOVA) using the time (before and during the study) as a within-subject factor and intervention type (tailored versus non-tailored) as a between-subject factor in the MindTap system.

The analyzes were performed after validating the data for t-test and ANOVA assumptions, with no violations. Whenever the sphericity assumption was violated, we used the Greenhouse-Geisser method of correcting the degrees of freedom. Following the discoveries of significant effects, we performed the posthoc pairwise comparison (using the Bonferroni method of adjusting for multiple comparisons) to determine which groups significantly vary from each other.

Results

We analyzed the change in the engagement of the different experimental groups and also the overall engagement with the two systems (SARA and MindTap) over time.

Change in Engagement on SARA Over Time after Introduction of the Persuasive Intervention

This analysis compares the overall students' activities on the SARA system before and during the persuasive intervention. The descriptive statistics on students' engagement in the SARA system before and during the intervention show difference in students' activities within the system. The engagement scores (average weekly view-event) of all the students (both the Experimental and Control groups) before introducing the intervention (M = 0.54, SD = 1.186) and during the intervention (M = 10.44, SD = 8.400) show mean level difference, as presented in Fig. 3. This means that students' engagement increased during the intervention. To evaluate the statistical significance of the differences, we performed one-way within-subject ANOVA. The results show a statistically significant difference in the students' engagement ($F_{1, 226}$ = 198.080, p = .0001, $\eta 2$ = .596). The pairwise comparison results demonstrated that students were more engaged in the SARA system during the intervention than before the intervention, p = .0001. While we saw a significant increase in engagement over time, a comparison between the groups under the experimental and control conditions before and during the intervention will help in confirming if the persuasive intervention caused the increase in engagement during the intervention.

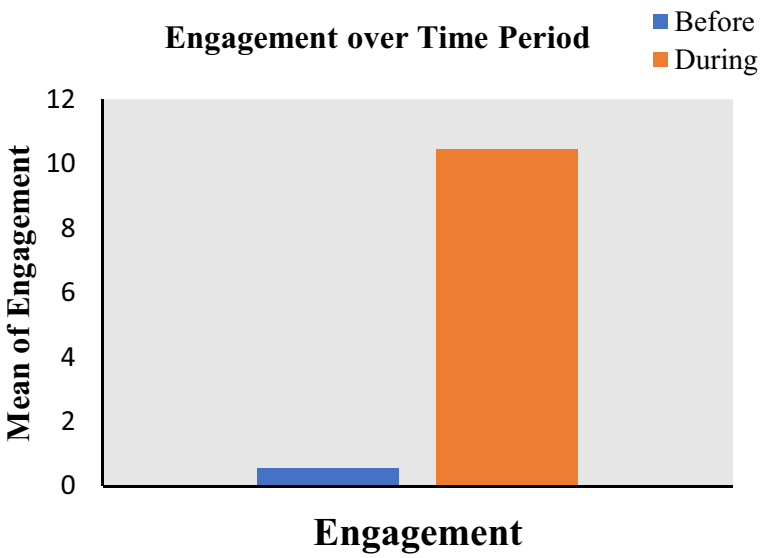


Fig. 3 The mean level of engagement in the SARA System before and during the intervention

Comparing Engagement in SARA of the Experimental and Control Conditions

To verify that the increase in engagement during the intervention was as a result of the persuasive intervention and not a result of their mobilization after seeing their midterm exam results, we compared the engagement of the group under the experimental condition with the control group. We performed a repeated-measure ANOVA using time as a within-subject factor and condition type (experimental and control) as a between-subject factor. The results reveal that there was a significant main effect of condition type on students' engagement ($F_{1, 226} = 20.55$, $p = .0001$, $\eta 2 = .056$). There was a significant difference in students' engagement between the experimental and control group over time. The pairwise comparison results show that students who used the intervention were more engaged than the control group (those that did not use the intervention), $p < .05$. Figure 4 shows the engagement of experimental and control groups over time. Specifically, students who used the SARA system with persuasion were more attentive to information provided by the system because they were more active with the system than the students in the control group.

Change in Students' Engagement on MindTap after Introducing the Persuasive Intervention

The descriptive statistics on three measures of students' engagement on MindTap for both groups (Experimental and Control) over time show that there are differences in students' engagement before and during the intervention, as can be seen in Fig. 5. To evaluate the significance of the differences, one-way within-subject ANOVA was conducted to test the effect of the persuasive strategies on students' engagement in their learning activities, i.e. if there was a statistically significant change in students' engagement before and during the intervention.

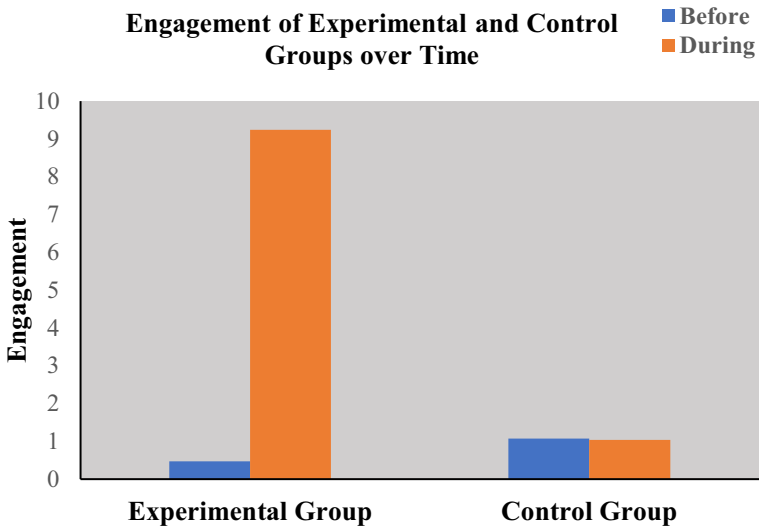


Fig. 4 Engagement of experimental and control groups over time in SARA

The results show statistically significant difference in students' engagement in learning activities for all the three measures: number of logins ($F_{1,206} = 428.319$, $p = .0001$, $\eta 2 = .774$), time spent ($F_{1,206} = 98.610$, $p = .0001$, $\eta 2 = .401$), and engagement score ($F_{1,206} = 2499.862$, $p = .0001$, $\eta 2 = .944$). The pairwise comparison result shows that the persuasive strategies promoted a significant increase in engagement for all three measures, $p = .0001$. An analysis comparing the engagement of the experimental group with the control group was done to confirm if the persuasive intervention promoted students' engagement.

Comparing Engagement on MindTap System between the Experimental and Control Group

We investigated the effect of the persuasive intervention on students' engagement (between the experimental and control groups) in their learning activities on MindTap.

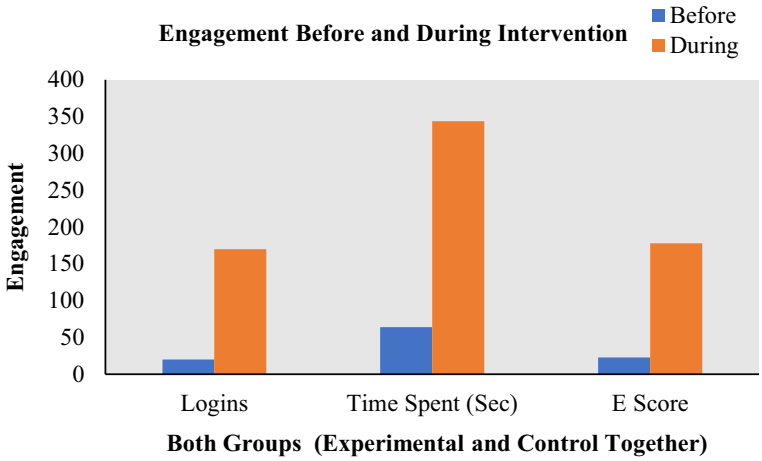


Fig. 5 Engagement before and during the intervention on MindTap

We performed RM-MANOVA to determine whether there exists a statistically significant difference in engagement between the experimental and the control groups over time. The results reveal that there was a significant effect of condition type on students' engagement for number of logins ($F_{1,206} = 371.947$, $p = .0001$, $\eta 2 = .644$), for the time they spent in the system ($F_{1,206} = 162.181$, $p = .0001$, $\eta 2 = .440$), and for their engagement score ($F_{1,206} = 3748.788$, $p = .0001$, $\eta 2 = .948$). The pairwise comparison results show that the experimental group was more engaged in the system than the control group (Fig. 6), $p < .05$.

Comparing Engagement in SARA of Tailored and Non-Tailored Groups

The descriptive statistics of students' engagement in the SARA system between intervention types (the Tailored and Non-tailored groups) in Fig. 7 shows that the tailored group had a higher mean level of engagement (M = 10.25, SD = 9.80) than the non-tailored group (M = 8.00, SD = 9.25). To examine the difference in engagement due to the effect of intervention type on students' engagement, we conducted an independent sample t-test. The results of the t-test show a statistically significant difference of intervention type on students' engagement, $t_{191} = 2.04$, $p = .043$. Specifically, the tailored group (where students used personalized persuasive visualizations), were more actively engaged than those in the non-tailored group (where students saw randomly assigned persuasive visualizations).

Change in Student Engagement Over Time in SARA Based on Intervention Type

The independent sample t-test results motivated a follow-up analysis to gain deeper insight on the change in students' engagement over time because of using the intervention. To achieve this, we performed a repeated-measure ANOVA using time as a within-subject factor and intervention type as a between-subject factor on students' engagements. The result shows that there is a significant main effect of the intervention type on students' engagement over time ($F_{1,191} = 9.49$, $p = .003$, $\eta 2 = .066$). The result means that a significant difference exists between the engagement of the tailored and the non-tailored (random persuasive strategy) groups. The results of the pairwise

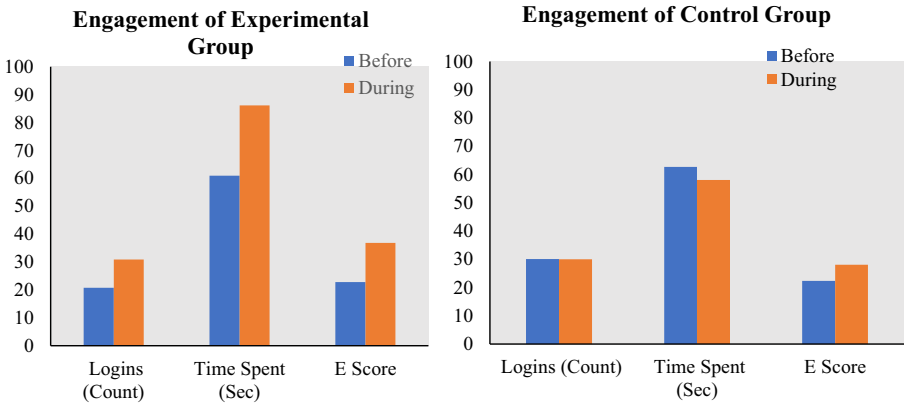


Fig. 6 Engagement of experimental and control groups in MindTap before and during the intervention

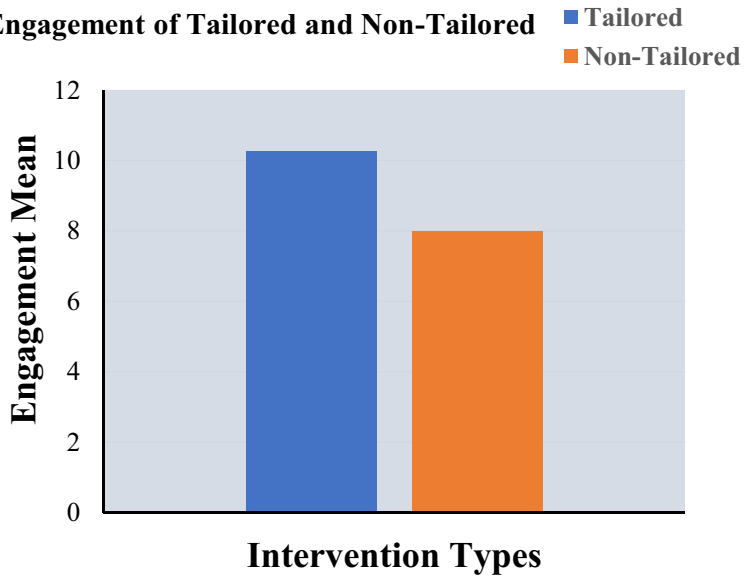


Fig. 7 Mean level of engagement for the intervention type on SARA

comparison show that students who used the SARA system with tailored persuasion versions were more engaged in the system than those who used the non-tailored version (as depicted in Fig. 8), $p < .05$. The student engagement in the tailored and non-tailored groups was similar before introducing the intervention, the tailored group (M = 0.51, SD = 1.201) and the non-tailored group (M = 0.58, SD = 1.177). However, during the intervention, the engagement of the tailored group was significantly higher (M = 12.50, SD = 9.076) vs. (M = 8.26, SD = 7.050) for the non-tailored group. The results mean that introducing the persuasive intervention promoted students' engagement and that tailoring the SARA system to the individual student's persuasive strategy susceptibility amplifies the persuasive effect.

Comparing Engagement on MindTap of the Tailored and Non-Tailored Groups

We used RM-MANOVA to test whether there was a statistically significant difference in engagement over time between the tailored and non-tailored groups in the MindTap System. The RM-MANOVA used time as a within-subject factor, the intervention type (tailored versus non-tailored group) as a between-subject factor. The dependent variables were the number of logins, time spent on the system, and engagement score. The results show no statistically significant difference in students' engagement between the tailored and non-tailored groups over time (as shown in Fig. 9), $F_{3, 174} = 2.454$, $p = .066$, $\eta 2 = .048$. Univariate tests also indicate that there was no intervention type effect on the individual dependent variables: $F_{1,174} = .094$, $p = .759$, $\eta 2 = .001$ for number of logins, $F_{1,174} = .985$, $p = .323$, $\eta 2 = .007$ for time spent, and $F_{1,174} = 3.453$, $p = .065$, $\eta 2 = .023$ for engagement score. So the difference in engagement between the tailored and non-tailored conditions was not significant.

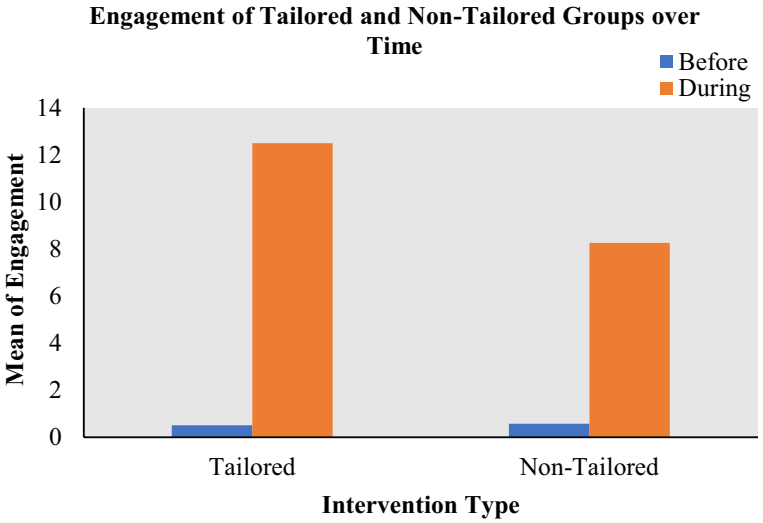


Fig. 8 Engagement on SARA of tailored and non-tailored group before and during the intervention

Discussion

The results of the field experiment show that the students in the experimental group became significantly more engaged in LSS activities after the persuasive intervention was introduced. The analyzes of logged data of the two LSSs - SARA and MindTap - showed that the students in the Experimental group engaged significantly in more learning activities in both LSSs than those in the Control group. This shows that applying socially-oriented persuasive strategies implemented as social visualizations in a LSS can lead to significantly increased engagement with the online learning environments in a blended university course. This result confirms previous results reported in the literature, e.g. (Vassileva et al., 2004; Brusilovsky et al., 2016). The social visualizations implementing the three socially-oriented persuasive strategies use familiar designs and can be implemented in any domain to represent various measures of student performance.

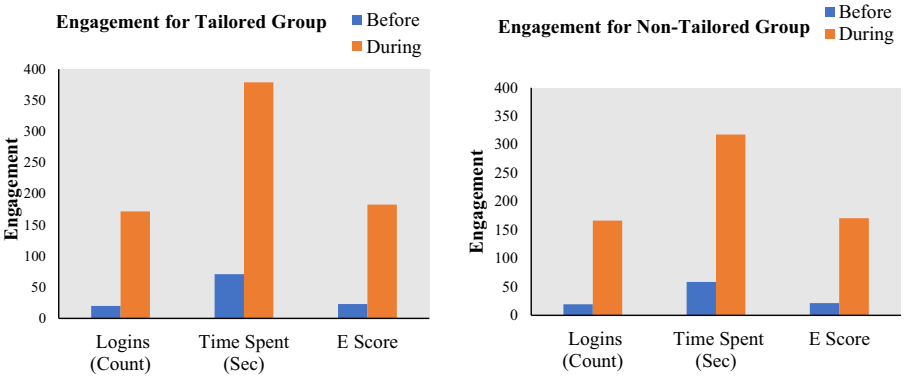


Fig. 9 Engagement of tailored and non-tailored groups in MindTap before and during the intervention

The results of analyses for the SARA system show that the Tailored group, in which students received visualization type implementing a persuasive strategy tailored to their persuasion profile, performed significantly more activities than the Non-tailored group (where students got a randomly assigned visualization type). The students in the Tailored group were more engaged in monitoring their progress than those in the Non-tailored group. The result confirms our hypothesis that personalization amplifies the persuasive effect and aligns with findings from other domains of persuasive technology applications, e.g. health (Orji et al., 2014; Orji et al., 2019). However, for the MindTap system, the difference between the engagement of the two groups was not significant, though the Tailored group performed more activities than the Non-tailored. One possible reason may be that some students may prefer to use traditional printed textbooks and engage in learning activities offline or use other materials available on the web – outside MindTap. It seems that the answer to our second research question depends on the learning context and more studies are needed.

Limitations and Future Directions

Our work has limitations. First, the evaluation study was limited to one university course and its duration – to one semester. Repeated studies would provide more evidence and insights into the effectiveness of the three explored persuasive strategies. Second, we chose to implement the three socially-oriented PT strategies as social visualizations. However, other implementation methods exist, for example, by using game mechanics or dialogue tools (nudges or conversational agents). Third, we explored only the three most commonly used socially-oriented PT strategies. The PSD model (Oinas-Kukkonen & Harjumaa, 2009) includes four other social strategies that can be explored. Fourth, our experiment could not predict the long-term influence of the intervention on students' engagement as they used the intervention for only 6 weeks. We do not know if students' perception of the persuasive strategies will change if they use the system for a longer period. Fifth, the students' engagement measure was only based on their online activities; their learning with traditional textbooks and structured or offline study sessions were not measured. Nevertheless, our work has demonstrated the effectiveness of the three socially-oriented persuasive strategies at improving students' engagement in their learning activities, and this will help PT designers in determining appropriate PT strategies to use in designing for students' learning improvement. Finally, the results of the research works are based on students' learning behaviour at a university and may not apply to other domains.

These limitations suggest many directions for future work. One important question to explore is whether the engagement of students translates into learning gains and better performance. Another one – the impact of culture on the susceptibility of students to different PT strategies. A large proportion of University students are international, with different cultural backgrounds. Previous work in our lab (Oyibo et al., 2019) has addressed cultural determinants on user susceptibility to persuasive strategies in physical exercise. However, we have not yet explored cultural determinants in the context of LSSs for blended university classes. In our future work, we may explore this direction, using personalization methods similar to (Brooks 2021).

Conclusion

This paper showed how social visualizations designed to implement three socially-oriented persuasive strategies could be deployed in a large blended university class to motivate students to engage more actively in their online learning support systems. In a field study, we showed that persuasive visualizations based on social learning, social comparison, and competition significantly increased the engagement of students in their learning activities measured by objective metrics. We also showed that tailoring the persuasive strategies (and the social visualization used to implement the strategies) to the persuasion profile of the students helps to amplify its effect on student engagement. While there exist educational systems that use competition in gamified educational systems and apply personalization to gamer types, e.g. (Challco et al., 2015), to the best of our knowledge, our work is the first to tailor the socially-oriented persuasive strategies implemented as social visualizations in a Learning Support System to students individual receptiveness.

Our work provides designers of online learning systems with simple way to implement socially-oriented strategies of PT to increase student engagement. The visualizations for the three persuasive strategies are domain-independent and use standard visualization techniques, which makes them simple to implement and understandable for students. Socially-oriented strategies of PT have been shown to be effective at helping people to achieve desired goals in various domains. To the best of our knowledge, however, their effect on motivating university students to improve engagement in their learning activities has not been explored. The evaluation of the effectiveness of the three persuasive strategies presented in this paper was performed in a field study in a large blended university course; therefore the significant increase of student activities represents the real-life implications of the three strategies on students' engagement in their LSS. Our research also shows that there is a need to tailor persuasive systems to individual student's receptiveness (susceptibility) to the persuasive strategies to increase their effectiveness.

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