DATA ANALYTICS AND PERSUASIVE TECHNOLOGY TO PROMOTE STUDENTS' ENGAGEMENT AND LEARNING

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By

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ABSTRACT

The use of interactive systems and internet technology nowadays enhance the process of learning as they allow educational resources to be effectively distributed and delivered to students. This gives students the opportunity to learn at their own pace and convenience. Hence, universities employ these computing technologies to aid in teaching and learning in order to meet the needs of diverse learners. Thus, students could engage in learning activities at any time and even outside the four walls of universities. Despite the usefulness of these systems, students find it hard to engage for a long time with these learning resources. They are distracted by so many activities such as chatting, playing games, listening to music, watching movies, etc. As a result, a wide gap exists in academic performance between successful students and unsuccessful one (those that drop out of universities). Therefore, there is a need for research on how to increase students' motivation to learn. The level of motivation of students to learn and progress in their education determine the length of time they spend on learning-related activities.

This research investigated the use of persuasive technology in encouraging students to spend quality time in their learning resources. Persuasive technology describes computer applications which change users' behaviour or opinion without using coercion or deception. Specifically, this research examined the effect of three social influence strategies of persuasive technology (social comparison, social learning, and competition) on students' engagement in their learning activities. Socially-oriented strategies recognize the fact that humans are socially-driven and thus, our feeling, behaviour or opinion is affected by that of others (social influence). The strategies were operationalized in a persuasive system as three versions of visualization using students' assessment grades. The persuasive system was applied to a real university course-based setting to determine its effect on students' engagement in their learning activities.

Quantitative and qualitative approaches were used in determining the effectiveness of the persuasive system versions implementing the three strategies in motivating the students to engage actively in learning activities. The results of this research show that the three socially-oriented strategies of persuasive technology employed can be used in educational software to influence students to achieve a positive goal in their learning. Precisely, the persuasive system attracted and motivated students to spend more time in their learning activities.

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DEDICATION

This work is dedicated to our Lord Jesus Christ and his Blessed Mother, Virgin Mary and also to my lovely daughter Oluebubechukwu Miracle Okolo and husband Israel James Okolo.

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CHAPTER 1
INTRODUCTION

Active engagement in learning activities has been observed as one of the factors that increase the learning success of students. Maintaining active engagement among students in the midst of distraction is sometimes difficult. However, motivation to learn acts as a driving force for active engagement. The motivation level of students towards learning affects their engagement in learning activities and consequently, their learning success. In contrast, the inability of students to maintain high motivation in performing activities (learning) beneficial to them is a great issue of concern. Low motivation for academic activities causes students to spend more time on other activities such as playing games, chatting, and socializing instead of learning. Hence, the motivational level of students to learn and progress in their education determines the frequency with which they engage and the amount of time they spend on learning-related activities.

Despite the significance of learning, reading, understanding and remembering various learning materials in the quest for knowledge can be a tedious and monotonous task, especially in universities. As a result, students make plans on how to succeed in their learning activities but find it difficult to motivate themselves and stick to their plans. In view of this, the research in this thesis investigates the use of persuasive technology (PT) to promote students' engagement in their learning activities to improve their academic performance. Specifically, PT is a set of technologies and techniques built into systems for changing users' behaviour, attitude, and opinions about an issue without using coercion or deception [35]. PTs achieve their behaviour change objectives using various persuasive strategies. The effectiveness of PT in motivating people to achieve certain goals has been established in various domains such as e-commerce [91] and health [81].

A wide gap exists in academic performance between successful students and unsuccessful one in universities. To bridge this gap, there is a need to create performance awareness among students offering a course. It will help the students to measure and understand their academic progress in relation to their peers. Thus, information technology can be employed in creating performance awareness. The ubiquity of technological devices and applications is drastically changing the way people live and perform activities in recent years. For example, students attend lectures with their smartphones, tablets, and laptops and use them to read, record, type or search for information in real time. Students continuously interact with their devices while at home or on the move (e.g. on the bus), thereby opening up new opportunities for designers to tap into and

design applications that will continuously motivate and empower students to achieve academic success through improving their learning behaviour. The applications can leverage PT to inspire students to engage more actively in their learning activities. Persuasive Technology offers the promise of motivating students to change their learning behaviours positively.

In education domains, teachers tend to apply the principles of persuasion in classrooms to encourage learning. However, technological innovations such as persuasive technology have moved the act of persuasion to the digital domain such that focus is now moving from human-human persuasion to computer-human persuasion. Human-human persuasion involves a human expert persuader trying to persuade a target audience or another person (persuadee) while in computer-human persuasion, a computer software motivates a target audience to achieve a specific goal. For instance, Epstein and Cullinan [30] used human-human social comparison in educating and persuading students with a behaviour disorder. On the other hand, Lucero et al. [61] inspire children to improve their reading and writing skills using computer software. Applications of persuasive technology in education focus most attention on investigating and developing fundamental theories and strategies for persuasion in the classroom. Persuasive technology, however, can be applied outside the classroom to assist and motivate learners without necessarily involving their teachers but using the power of technology and other learners (social influence). Social influence describes changes in an individual's behaviour or opinions which may be intentional or unintentional [42] caused by the influence of other people. Research has shown that social influence can be an effective strategy for motivating behaviour in the health domain [81]. Also, PT driven by social influence-oriented strategies such as social comparison, social learning, and competition has been shown to be effective at increasing people's capability to accomplish target behaviour [91] in e-commerce.

There exists a gap in research on how social influence strategies of PT can be applied to promote desired behaviours in education and whether it will be effective. As a first step towards closing this gap, this research focuses on the design, implementation of a persuasive system to encourage improved learning activities, and investigation of the system's effect on students' learning activities. The three socially influence strategies employed in this research are social comparison, social learning, and competition.

This thesis is directed to answer this broad research question: *can socially-oriented PT strategies be used to motivate students to increase their learning engagement and improve*

academic performance? The research in this thesis aims to make contributions to the area of educational technologies, by investigating ways to increase students' engagement through the use of persuasive technologies based on social influence.

1.1 Problem Statement

The number of students dropping out of higher education has been an issue of great concern to universities and governments. Research [8] has shown that poor academic performance is one of the major reasons why students drop out of universities. According to persistence in post-secondary education in Canada report, about 14% of first-year students drop out of higher education institutions as a result of academic performance [1]. The report suggested that those students who drop out struggle with study behaviour and academic performance. Moreover, Araque et al. [8] reveal that low motivation for academic activities results in poor academic performance. Hence there is a need to assist students to sustain high motivation for academic activities. To achieve this, many students need to change their behaviours to engage more actively in their learning activities in order to succeed.

Students often find it hard to engage in learning activities. The fast-paced world makes it difficult for them to engage deeply for a long time. This is a very big problem because engagement and commitment are fundamental to learning. Learning requires concentration. On the other hand, students often do not have an opportunity of viewing and comparing their academic performance with that of their peers to evaluate their success. Research [53, 91] on social influence has shown the efficacy of the power of similar others in shaping behaviour because we often look at other people to know what we should be doing. Therefore, there is a need to develop technological solutions to engage learners, keep their attention, and get them committed to learning activities. One such solution is the use of PT. Persuasive technologies have tapped into the social influence theory [90] to develop persuasive strategies that can be used to motivate people to adopt a desirable behaviour.

Most of the earlier research works that applied PT in education were not based on computer-human persuasion but on human-human persuasion. For instance, Epstein and Cullinan [30] used human-human social comparison in educating and persuading students with a behaviour disorder. Other educational-oriented PT focused on the use of PT in the classroom by the teacher to motivate the students; PT has been applied in teaching of complex topics/courses to students. Most research

works on PT in education focus on the principles and strategies for persuasion in the classroom. Thus, a technology, which gives the students an opportunity to monitor their performance and that of their peers, can be employed to keep them deeply engaged in their academic activities. PTs driven by social influence-oriented strategies such as social comparison, social learning, and competition have been shown to be effective at increasing people's capability to accomplish a target behaviour [53, 73, 91]. Hence, this thesis aims at addressing the problem of low motivation of students to engage more frequently in their learning activities.

Research on applications of PTs to bring about the expected change of attitude and/or behaviour has shown that personalized PTs are more efficient than a one-size-fits-all approach. Thus, the research in this thesis will also investigate and compare the effect of personalized PT and non-personalized one.

1.2 Overview of Thesis

The organization of this thesis is as follows: In chapter two, I discuss the background theories and principles employed in this research. This is followed by a review of related research works that are relevant to this research. Chapter three presents a detailed description of this research context, the approach and the process involved. Chapter four discusses user study carried out to determine the susceptibility of users (students) to the social influence strategies of PT used in this research. The study helps in identifying the applicability of the strategies to the users. Chapter five presents a detailed explanation of how the three social influence strategies are operationalized in a persuasive system. It describes system design, development, and implementation while Chapter six presents full details of an experiment performed with the designed persuasive system to determine its effect on students' engagement in their learning activities. Next, Chapter seven describes the analysis of data to determine the effectiveness of the system and its impact on students' engagement in their learning activities. It also contains the results of data analysis and discussions on students' feedback to the system. Finally, I present the discussions on the implication of the results to students' learning, summary, contributions, limitation and future works in Chapter eight.

CHAPTER 2

RESEARCH BACKGROUND AND RELATED WORKS

Interactive systems affect the attitude and behaviours of people in different ways. Sometimes their design could create an inadvertent side effect on people [71]. Persuasive technologies (PTs) are implemented as interactive software systems and active research on PTs focuses on how software systems can be designed to motivate behaviour change on users without creating inadvertent contra-effects on them. To provide background for this research, I reviewed literature encompassing the following topics: Persuasive technology and Fogg's Persuasive Tools, Persuasive System Design (PSD), Gamification and Persuasive Technology (PT) in Education and Learning, Social Visualization and Persuasive Visualization, and Personalization of Persuasive Strategies.

2.1 Persuasive Technology and Fogg's Persuasive Tools

The earliest form of persuasion was human-to-human persuasion. It involves a person (persuader) trying to persuade another person (persuadee) through speech, discussions or actions. This form of persuasion has some limitations which include the number of people it can reach, the ability for it to continue the persuasion over an extended period of time, the ability to persuade different people at the same time, etc. These limitations led Stanford researcher B.J. Fogg to invent the notion of computers as persuasive technology (PT), a ubiquitous and sustainable way to influence users for behaviour or attitude change. PT is defined as a set of technologies and techniques built into systems for changing users' behaviour, attitude, and opinions about an issue without using coercion or deception [35]. PTs achieve their behaviour change objectives using various persuasive strategies. The primary aim of PTs design is to change the attitude and behaviour of its user to achieve a positive goal. The goal sometimes benefits only the user (persuadee), for example, in the area of health and education. The persuader tries to encourage system users to live a healthy lifestyle by eating healthy foods and managing their health conditions adequately or to persuade students to participate actively in their learning activities. But in e-commerce, the persuader and persuadee gain from the persuasive systems. The persuader through tracking the online activities of their customers, recommends them products and services of their interest, this increases the patronage of customers to the company (persuader).

The effectiveness of PTs in motivating people to achieve certain goals has been established in various domains such as health [75, 81], e-commerce [52, 91], energy conservation [43, 97], physical activities [36, 96], and education [7, 38]. The domains of e-commerce and health have received most significant attention. In e-commerce, it involves tracking and analyzing customers' online activities to recommend goods and services of interest to them and thus to improve their shopping experience. In health, researchers use PT to motivate users to live a healthy lifestyle, such as eating a balanced diet, avoiding smoking and drug addiction, and taking preventing measures about diseases to avoid sickness. Energy conservation is another domain of PT application. In this domain, users of PT are provided information on their electricity consumption to motivate them for conservation behaviour. This is normally achieved through a display of energy consumption data to increase awareness. Physical activities is another area that PT has gained ground. PT applications in this area, try to promote users' participation in physical activities by providing a fascinating user experience for monitoring progress and benefits of exercising. Moreover, the education domain has equally witnessed the effect of PT. It has been applied in teaching complex topics, motivating students to enter higher education, and in increasing students' attentiveness in class.

Initially, the primary use of a computer was for data storage and computations. However, with the advance of mobile and ubiquitous computing, equipped with inexpensive sensors, computer tools have much broader application areas ranging from health monitoring, tracking of items, medical diagnosis, monitoring the progress of physical activities and so on. This technological advancement makes people rely on computers for many things. This reliance and the increasing use of computer tools by virtually everyone has made it a perfect tool which can be used to influence people to change their behaviour and attitude in a wide variety of contexts. Based on this, Fogg [35] defined seven types of persuasive technology tools. According to him, "*persuasive technology tool is an interactive product designed to change attitudes or behaviours or both by making the desired outcome easier to achieve (p.32)".* The seven types of persuasive technology tools are as follows: *Reduction, Tunnelling, Tailoring, Suggestion, Self-monitoring, Surveillance, and Conditioning*.

Reduction: This works on the assumption that sometimes the processes required for a behaviour change to occur might be too complicated for users of the system to accomplish. Hence, reduction involves using a computer to simplify the complex behaviour to motivate the users in achieving it.

Tunneling: It involves providing users with a step-by-step guide on how a process can be carried out to encourage them to perform the desired behaviour.

Tailoring: This acknowledges the fact that if computer provides users with information which are specific to their desires, personality, problem context or other personal issues, the users will be more motivated to use the system. Therefore, tailored content has been shown to be more effective at helping people to achieve the desired goal. According to Fogg [35], this is because people are highly active in processing information personalized to them which they think is relevant to them.

Suggestion: This requires the technology to provide a recommendation for an event at the proper time. The technology must be able to determine the right timing for its suggestion before it can be able to persuade.

Self-monitoring: It involves users checking their behaviour and attitude about an issue and adjusting it positively to achieve a specific objective. It sustains users in continuing to perform the target behaviour by providing them with the means to measure their progress.

Surveillance: This works on the assumption that people tend to conform to norms or change their behaviour when they know that somebody is monitoring them. A thirty party monitors users' behaviour to assist them in performing the target behaviour. When there is a reward or punishment attached to the performance of the target behaviour the use of Surveillance becomes more effective.

Conditioning: This involves sustaining people in performing the target behaviour with the use of points and badges. Users are encouraged to continue the behaviour by increasing their points based on their progress in accomplishing the behaviour.

According to Fogg [35], the real implementation of these tools involves a combination of two or more of the seven categories in PT software to realize a specific outcome. He stated that persuasive tools have three main functions:

i) they simplify the target behaviour – sometimes the processes needed for a behaviour change to occur might be difficult. With the help of technology, the processes are made easier to accomplished.

ii) they guide users through a process – instead of presenting users with difficult processes which they might find difficult to achieve. Step-by-step simple processes are provided for users to encourage them in performing the process.

iii) they manipulate information to motivate – information is operated and presented in various ways to motivate users**.** Different users can be inspired in diverse ways by the system at the same time.

The choice of tools to use in PT software depends on the desired goal that the designers of the software aim to achieve with their design. In addition, Fogg specified that the development of effective PTs involves eight processes shown in Figure 2.1:

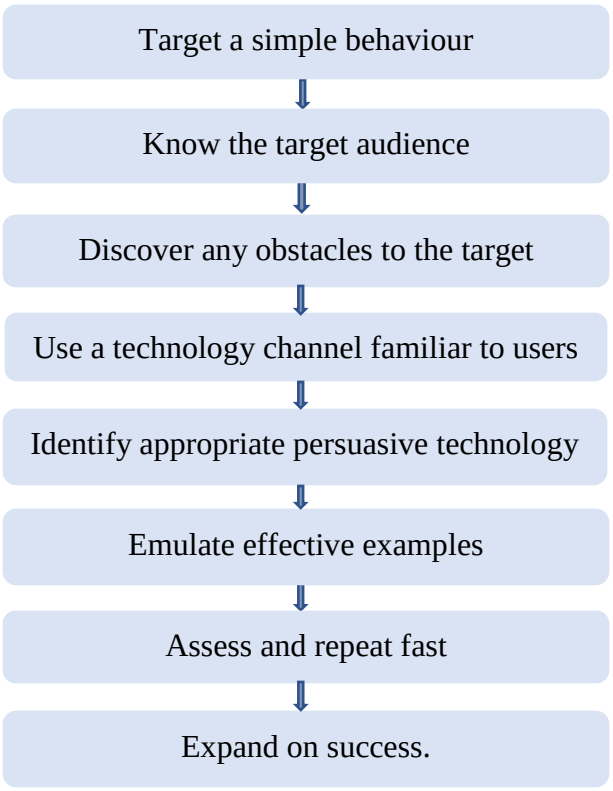

Figure 2.1. Fogg Eight Steps Processes for Effective PTs Development

Following Fogg's guideline, I targeted a simple behaviour, which is increasing students' engagement in their online learning activities; the target audience is students taking a first-year Biology course at the University of Saskatchewan. Students are distracted by many things (such as social activities, playing games, peer group influence, etc.), which makes it difficult for them to engage fully in their learning activities. They often have a wrong impression of what others are doing and don't know how to compare themselves with their classmates. To identify appropriate technology examples, I reviewed related literature [53, 63, 78, 83, 91] which has explored the effect of social influence strategies and found that research [75, 78, 91] has recognized social

influence strategies as very efficient for motivating behaviour and attitude change. I started the persuasive intervention design with one course and one class. Future work can expand on success and include more courses.

2.2 Persuasive System Design (PSD) Framework

Based on Fogg's work [34], Oinas-Kukkonen et al. [71] defined the process model, main issues to address, and the design principles for use in the development and evaluation of persuasive systems. Oinas-Kukkonen et al. [71] established twenty-eight persuasive system design principles. These design principles have four main categories: primary task support, dialogue support, system credibility support, and social support.

- The primary task support involves activities required by the users to perform their basic tasks. The principles consist of reduction, tunneling, tailoring, personalization, self-monitoring, simulation, and rehearsal.
- Dialogue support requires the system to provide users with an opportunity to send their feedback to the system. The design principles that can be used to implement computer-human dialogue comprise praise, rewards, reminders, suggestion, similarity, liking, and social role.
- System credibility support defines design principles which PT systems can implement to make them more trustworthy and more persuasive. It includes trustworthiness, expertise, surface credibility, real-world feel, authority, third-party endorsements, and verifiability.
- Social support leverages social influence strategies to motivate users. It includes social learning, social comparison, normative influence, social facilitation, cooperation, competition, and recognition.

Besides these design principles, Oinas-Kukkonen et al. [71] suggested that the design or evaluation of persuasive systems is supposed to consider seven postulates. The postulates are as follows:

1) Persuasive technology systems should be adapted to reflect changes in the process of persuasion.

2) Users of persuasive systems will be more influenced when the system is consistent and provides them with the opportunity to make a commitment that will affect behaviour changes.
3) There is two approaches to persuasion; direct and indirect approach. Persuasive systems may incorporate the two approaches. Direct persuasion motivates some users while indirect persuasion persuades other users.
4) Persuasive systems should provide users with a medium for incremental steps which will help them to achieve the target behaviour.
5) False information should not be used to make users change their behaviour or attitude, i.e. the system must be honest.
6) The timing for persuasion ought to be adequately considered, to avoid distracting users when they are performing their basic task.
7) Persuasive systems should be simple to use and should help users solve their problems.

With the existence of these strategies, design principles and postulates, PT designers select persuasive strategies and techniques based on their effectiveness and suitability for solving a particular problem [71]. For instance, scarcity from the Cialdini [21] persuasive strategies is very important and effective when applied in e-commerce domain but might not be relevant in the education or health domain.

2.3 Gamification and Persuasive Technology (PT) in Education and Learning

In the last few years, several interventions have been carried out in education aimed at using interactive systems to address some problems that students encounter in learning. According to Fogg [35], the use of interactive systems as persuasion mediators have six main benefits:

1) The system's ability to persist an intervention without getting tired – unlike humans that can get exhausted or bored when performing an activity for a long time, computer systems can continue to execute a task for a period of time.

2) The system can gather and deliver anonymized information – information security is very essential in all aspects of life. The computer system can collect and distribute large information while maintaining the privacy and security of the information.

3) Information is essential for knowledge. Computers have large storage and can give access to stored data and manipulate the data fast.

4) Information can be presented in different ways to diverse people to motivate them – depending on what the system aimed to achieve, it can adapt information to different users based on their preferences.

5) Information can be viewed at the same time by numerous people - real-time access to information is made possible for several people at the same time without constraints.

6) Information is available and accessible everywhere without human presence – humans after a while can forget something they know but stored information on systems are always reachable.

As a result of the benefits of interactive systems, some educational interventions implement it using gamification or PT to bring about a positive attitude or behaviour change that improves learning in general. Research on gamification and PT usually study behavioural or attitudinal changes as a result of the interaction of the user with the system.

The increasing use of computer games nowadays and its motivational pull has led to an increase in the application of gamification in several domains such as marketing [99], education [11, 24] and health [50]. Gamification means using game elements and techniques in non-game application contexts [25]. These game elements are usually implemented in the form of points, badges, levels, challenges, rewards, and leaderboard [99]. Research has established that gamified systems and services increase people's participation, engagement, loyalty and competition [99]. As a result, several domains employ game elements in their system design to achieve a specific goal. For example, e-commerce companies incorporate game components on their websites to inspire users to generate a high rate of activities on their site [99].

Application of gamification in the education domain is not new. Several research works that focus on the use of gamification concepts to motivate students learning engagement in higher institutions exist. For instance, Charles et al. [17] established that a gamified system used in teaching programming course to undergraduates resulted in increased students' engagement and improved performance in examinations and coursework. Dominguez et al. [29] investigated the use of gamification to improve 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. [11] implemented gamification in a college course using points, challenges, levels, leaderboard, and badges. They measured the impact of gamification on learning experience by comparing data from the gamified and non-gamified system. Their results reveal that the gamified system resulted in improved attention, participation, and performance of students. Other research on the use of gamification includes: use of achievement badges to change students' behaviour [44], leaderboard to improve students' engagement and academic performance [59], and research on the use of gamification to teach challenging course which shows that gamification increases students' participation, interaction in the course, and the percentage of students that passed the course [48]. These applications of gamification in education have shown that it can effectively be used to achieve improved academic performance of students.

Furthermore, persuasive technology applications have been recognized to be effective at encouraging people to adopt a specific behaviour and attitudinal change. According to Devincenzi et al. [26], "The *PTs can be applied as learning aid instruments, acting directly and/or indirectly in the areas of Social Assistance, Health, Environment, Research and Development, Education and Advertising (p.1)*". Most existing PT applications are, however, focused on e-commerce [4] and health [81] domains. Research has shown that they are capable of motivating people to achieve a target goal. Nevertheless, researchers have recognized that education can gain from PT as well. For example, Filippou et al. [33] in their research discovered that students develop study plans to help them improve their grades, but they find it difficult to keep to their study plans. For this reason, they suggested that PT can be applied in education to influence students to improve their study habit. Devincenzi et al. [26] suggested that application of PTs in education will constantly remind the students of their learning. Equally, Mintz et al. [65] proposed theoretical considerations for PTs design that will be suitable for the complex school system. They suggested that PT design strategies can be adapted to the educational context to bring about a positive change of attitude and behaviour of students. Moreover, Christy and Fox [20] investigated the effects of social influence strategy (Social Comparison) on students' academic performance in a virtual classroom. They reveal that social comparison can influence women academic performance in maths. Furthermore, other research works which applied PTs in education include: motivating people to enter higher institution using PT [95], leveraging persuasive mobile applications for self-learning [86], the EuroPLOT Project which applied PT in teaching and learning [12], review of PT applications in education [26, 66], the application of PTs for people with learning disabilities [2,

13, 67], PTs for teaching courses [7, 9, 12], application of PTs for self-regulated learning [38], Personalization of PTs to encourage students active engagement [72], and the effect of cognitive ability on persuasion susceptibility [3].

Additionally, Chou et al. [19] applied persuasive technology with gamification to influence user behaviour. In their research gamification was used as a trigger for target behaviour change. Similarly, [60] has shown that gamified systems aim to change users' intuition, which will consequently increase their engagement and involvement in the use of the system. The research established that gamification is a form of persuasive technology for three reasons: it makes the desired behaviour easy to achieve, it can change behaviour or attitude, and four of persuasive tools (tunneling, self-monitoring, surveillance, and conditioning) overlap with mechanics used in gamification systems. Hence, implementing PTs involve the use of persuasive strategies and these strategies are abstract and theory-driven, so to operationalize them, often game elements are used. For example, in persuasive systems, competition strategy is usually operationalized using leaderboards that rank users based on their points to create a competitive environment that will motivate the users in performing the target behaviour. The points and leaderboard employed in the implementation of the competition strategy are also game elements which help in the operationalization of the strategy.

2.4 Social Visualization and Persuasive Visualization

According to Fogg [35], persuasive systems referred to as social actors have the potential of maintaining their social influence capability in peoples' absence and enable behaviour or attitude change. In line with this research, Fogg [35] advocates that computers are efficient persuaders as they sustain a high level of interactivity and could be made to adjust influence strategies based on situations and context. Normally, technologies enable and streamline the process of behaviour change by influencing users through services built on top of them. These services sometimes use a visual depiction (visualization) of data to support the human perception of the information. Visualization has various forms such as information (data) visualization, social visualization, persuasive visualization, etc. *Information visualization* presents facts in a way that will make it easy for people to read, understand and interpret it. Visual perception researchers have shown that

visual information presentation (visualization) is more persuasive than text [18]. Thus, visualization acts as an effective means of attracting attention to a specific topic/object.

Social visualization focuses on people in a group and how they relate to each other and form a community. This type of visualization usually increases people's awareness of the activities happening in their community to encourage them to participate in those activities. Research on social visualization has shown its efficacy at motivating people for a desired goal. Gilbert et al. [37] show that social visualization of code repository positively influenced distributed developers. The visualization inspires developers to contribute to their community. It also provides incentives for the developers and allows them to send feedback. Equally, Valkanova et al. [97] investigated the use of visualization as a means of increasing 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's energy consumption and provides an opportunity for people to send their responses. Sun and Vassileva [93] used social visualization to encourage users to contribute to an online community resource by displaying the contribution of each of the users in the community. Also, Vassileva [98] established that social visualization of users in an online community which gives users opportunity to view and compare the activities of each other resulted in increased participation in the online activity. DiMico et al. [28] studied the impact of a graphical visual display of individual speaker-participation in group behaviour during a collaborative task. Other research works which used social visualization to increase the performance of an activity include: social comparison and social visualization for achieving sustainable behaviour change [41], implementation of competition, collaboration and informational anonymity with social visualization [40], a social visualization that encourages students to discover relevant resources in their course [47], etc.

Persuasive visualization is the use of visual representation of data to influence individuals towards desirable behaviour or attitude change. It usually presents specific opinions that will support the advocacy for change of behaviour/attitude. Data displayed are specially chosen to convince the user on the need for a change of opinion or attitude. Research on the designs of persuasive visualizations to encourage attitude or behaviour change has begun in recent years. Holstius et al. [46] established that a simple visual display of recycling habits positively influenced students' recycling habits. This display resulted in many students effectively changing their recycling behaviours. Similarly, in the domain of water conservation, persuasive visualization was

integrated with low-cost water flow sensors to inspire public awareness and sustainable behaviour around water preservation [58]. The visualization brought about a reduction in water consumption in the long-term [58].

Furthermore, according to Berinato [23], context is the most important aspect of data visualization as it defines the audience, the message, and the place. Hence, to create a good persuasive data visualization, there is a need to determine the proper context. Good persuasive visualizations according to Berinato are those with outstanding design implementation and high contextual awareness. Equally, Chih et al. [18] defined visualization as communication process which identifies information patterns in data and presents it as an information graphic and the more persuasive the graphic, the more efficient the presentation. Visualizations use colours choice, visual grouping, and variations to emphasize interesting points. Pandey et al. [84] in their study investigated the influence of visualization on people's behaviour or attitude. They found that the persuasive effect of visualization is dependent on the initial attitude of participants about the topic and that information presented as charts are more persuasive to those who do not have a strong initial attitude while table presentation of data is more persuasive for those with the strong initial attitude of the topic.

Both social visualization and persuasive visualizations tend to bring about the desired behaviour or attitude change by motivating users to perform a specific goal. This research uses both social and persuasive visualization to encourage students' engagement and improve learning. Biology class represents the students' community. Social comparison, social learning, and competition which allows students to view, compare and compete with other students in their class (community) to influence them for the desired goal were employed.

2.5 Personalization of Persuasive Strategies

Research [54] has shown that individual differences exist in people's susceptibility to PT strategies. Hence, it is advocated that persuasive systems should be personalized to users' strategy preference to improve its efficiency. Personalization means delivering PTs designed with the strategies to which the user is most susceptible. It acknowledges the fact that users react differently to several persuasive strategies and the reaction affects the effectiveness of the strategies in motivating the users. Several studies [47, 55, 74, 77, 89] have shown that personalizing PTs to users is more effective in achieving behaviour or attitude change than a "one-size-fits-all"

approach. There is growing evidence that personalized PTs are more effective than one-size-fits-all. For instance, Orji et al. [77] have shown that personalizing persuasive gamified health system to user types influences their effectiveness in achieving the desired goal. In e-commerce, for example, Siawsolit et al. [89] have shown that a personalized assistant can be used to influence customers to purchase healthy food. Similarly, Chih et al. [18] emphasized that personalizing persuasive visualization to users makes the visualization more interesting to users, thereby improving its influence on the users. Furthermore, Kaptein et al. [55] established that personalizing PT applications makes them more effective. They suggested that personalization of PTs can be achieved using persuasion profile constructed using implicit or explicit measures. Persuasion profile is a measure that estimates the susceptibility of an individual to persuasive strategies to determine the most effective strategies for that individual.

Personalization of persuasive output requires the system to know the users' characteristics. The users' characteristic measures can be made available in various ways, such as the use of a standard self-report questionnaire, mobile sensors, online interactions, application logs etc. These measures are categorized into explicit or implicit measures. Explicit measures employ self-report questionnaire to obtain the desired user features. Implicit measures use online interactions, application logs, mobile sensors or behaviour logs of the user on the system for measuring susceptibility to persuasive strategies for adaptation of the system to the users. Previous research on PTs has revealed various users' features which personalization can employ. These users' features were used to build persuasion profile for the users. For instance, Kaptein et al. [55] models constructed users' profile based on their susceptibility to Cialdini's persuasive strategies. To create the models, they used a specially designed questionnaire. They have also explored learning the persuasion profile by observing user reactions to a range of persuasive strategies (i.e. implicit measure), but this approach requires a lot of training data. Oyibo et al. [83] have shown that persuasion profile can be created using demographic data about the gender or age of the users. Adaji et al. [5] demonstrated that persuasion profile for e-commerce applications may be created by mapping shoppers' types to Cialdini's persuasive strategies. Moreover, [45] constructed their personalization model for adapting persuasive messages using the Big Five personality survey [64], which comprises of Extraversion, Neuroticism, Agreeableness, Conscientiousness, Openness. They realized that personalizing messages using personality traits increases their effectiveness. Some researchers combined personality types and bridging studies to discover the

affinity to persuasive strategies of different personality types. For example, Orji et al. [76] first discovered the users' gamer types using a validated questionnaire (BrainHex). Then they used a large-scale study to map users with known BrainHex types to persuasive strategies they are more responsive to. Also, [82] shows how Big five personality traits can be mapped to Cialdini's persuasive strategies and be used to adapt a persuasive application to users.

In general, the choice of users' features to represent in the persuasion profile depends on the chosen spectrum of persuasive strategies in the specific domain of the application. There are validated tools developed for measuring the susceptibility of users to various persuasive strategies. The tools have been adapted to different domains to measure people's susceptibility to PT strategies.

In this research, personalization is achieved by determining the students' persuasion profiles using validated tools for the set of persuasive strategies chosen, and then selecting the most effective strategies for each individual student according to his or her persuasion profile.

2.6 Theories of Motivation and Learning

Motivation is one of the important factors that lead to success in every life endeavour. It describes the desire of an individual to achieve a definite level in some aspects of life. In education, it refers to students yearning to realize a certain level of academic performance or learning. There are two kinds of motivation: internal and external motivation [85]. Internal motivation is an interior state that compels one to perform certain activities to achieve a specific goal. The driving force for this motivation is the enjoyment that emanates from the performance of a task. External motivation describes the influence of outside force to an individual to achieve a definite goal. The gain of performing an activity impels people into doing it. There are other factors that affect the level of activity performance apart from motivation. According to research, motivation, ability (possession of knowledge and skills) and environmental factors (availability of information and resources needed) are key factors for effectively accomplishing a performance level in a task [94]. Shelstad et al. [94] indicate that achievement of a performance level in a task is dependent upon the interaction between motivation, ability, and environment as shown in Figure 2.2. According to them, the key to achieving high performance in activity might be one of the factors in some occasions. For example, in this research, all the students have the ability they need for their

learning in the university as all of them successfully graduated from high school. Moreover, the students have access to all available resources necessary for their learning. Therefore, for these students, motivation may be the required factor needed for them to improve in their learning activities.

According to Fogg Behaviour Model (FBM) [34], the three factors (motivation, ability, and trigger) are the core elements that cause behaviour change to occur. He indicated that if a behaviour change does not happen with the model, it means that one of the elements in the model is missing. Research works on persuasive technology and behaviour support systems have shown that the model can be applied using different PT strategies and techniques to bring about a change of specific behaviour of an individual. For this research, students have the ability, but they need to be motivated to use their ability in learning activities. The need to provide the motivation and trigger that the students require for their learning leads to the design of persuasive social visualization. The visualization provides the motivation through the presentation of grades of high-performance students. And the trigger through constantly reminding the students of their learning progress in relation to their peers.

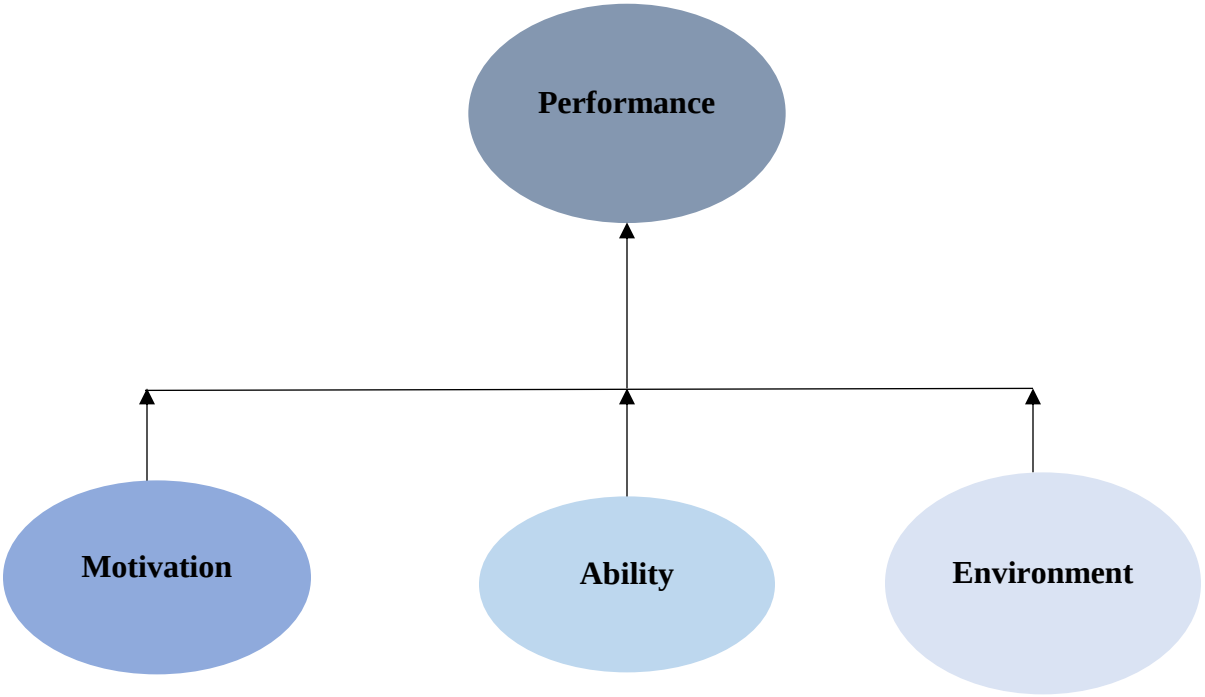

Figure 2. 2. Motivation, Ability, and Environment as determinants of Performance, adapted from Shelstad et al. [94]

2.7 Knowledge-attitude-behaviour (KAB) Model

The model (Figure 2.3) stresses that knowledge is an important prerequisite for the intentional performance of a desired behaviour [68]. According to the model, changes in attitude always occur as a result of the acquisition of new knowledge relevant to that attitude. And accumulation of attitude change results in behaviour change. The model uses information provision as a procedure for encouraging people to change behaviour. There are various types of knowledge [68]: Awareness knowledge and How-to knowledge. Awareness knowledge enhances people's motivation through the provision of information which increases attention and awareness of their situation, whereas, how-to knowledge provides motivated people with ways to achieve their goal. In all educational interventions, keeping students motivated and attentive to their learning activities is an essential element that leads to improving the learning outcome; impact awareness and/or how-to knowledge is a step to achieving that.

Research [88] has shown that increasing awareness and knowledge of students about e-waste resulted in a positive change of attitude about e-waste generation and disposal. Schrader et al. [87] revealed the KAB model can be employed in complex environments to measure performance and learning, as it will help to examine the behaviour changes that occur. Also, Kaur et al. [56] investigated the relationship between KAB and information security awareness. They established that employees information security awareness influences their attitude and behaviour towards the integrity and confidentiality of the company's information.

In line with the KAB model, this research implemented social-oriented persuasive strategies to motivate for learning and facilitate awareness knowledge and how-to knowledge respectively.

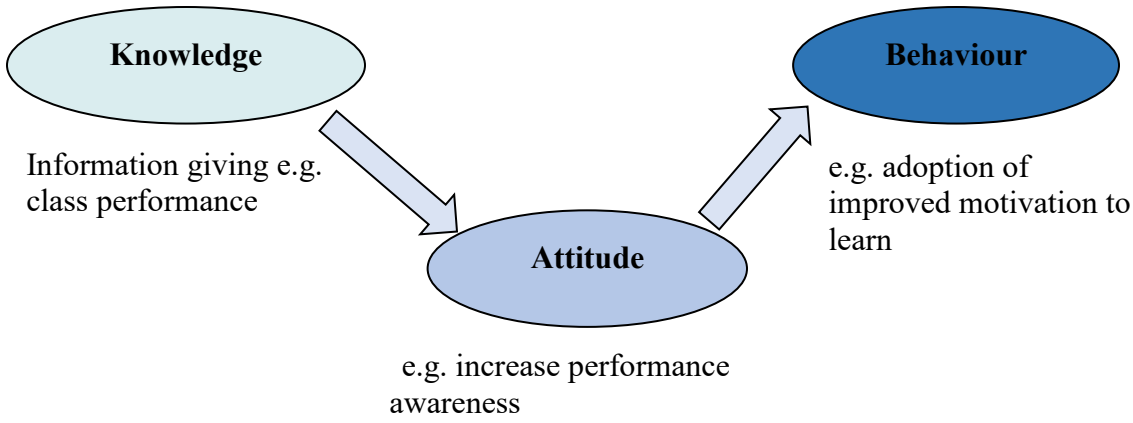

Figure 2. 3. Knowledge, Attitude, and Behaviour Model, adapted from [62]

CHAPTER 3

RESEARCH METHODOLOGY

Education is concerned with providing students with values, attitudes, knowledge, and skills that will be beneficial to them in life. Students acquire education through a formal process that encourages them to learn. The process of education in higher institutions allow students to learn through teaching, reading, practising, quizzing, experimenting, studying, etc. Interactive systems and internet technology enhance this process and allow educational resources to be effectively distributed and delivered to students. Several frameworks had been developed to use these technologies to enhance teaching and learning in education. Higher institutions nowadays employ technologies such as online learning in addition to traditional teaching methods to give the students the opportunity to learn anywhere and at any time to meet the needs of diverse learners. Hence, students could engage in learning activities at any time and even outside learning institutions. This research investigates the effect of technology such as persuasive technology on students' engagement in their learning activities. It received behavioural ethics approval with approval number BEH# 17-431.

3.1 Research Context

The setting for this research is an introductory Biology class (BIOL120) offered at the University of Saskatchewan during the 2018 Winter term. The class had 690 registered students. The students had the following resources recommended by the Biology Department for the course; Online MindTap, MindTap textbook, and Structured Study Sessions. Students' access to all the resources was optional. Online MindTap is a learning platform which 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. Each topic has practice exercises which cover all areas of the topic. Students can learn in the online MindTap through the study of the e-book, practising exercises and the use of multimedia tools. Though the use of online MindTap was optional and only 10% of the students' final grade will come from its quizzes, 80% (549) of the students in the class signed up for the use of online MindTap. Students also have their physical MindTap textbook which they can study for the course. Also, there is Structured Study Sessions were peer mentors assist students to review, practice, and master course materials.

Furthermore, all registered students in the course had access to the learning management system (LMS) called Blackboard Learn. The LMS is an e-Education platform for communicating course contents, materials, and assessments to students, and for connecting course instructors with their students. Students receive class schedule changes and other important messages via the LMS. Students also receive weekly personalized messages from Student Advice Recommender Agent (SARA) integrated with the LMS, coaching them to access useful learning resources and services. A course content expert constructs the messages from templates with constraints and triggers. SARA is an application that sends weekly course-based personalized messages to students regarding useful learning resources and services based on their individual learning needs [39]. It is based on predictive models which use the students' activities in a course to determine appropriate advice for each student.

3.2 Research Approach

The nature of this research is exploratory and confirmatory. It aims to determine how to design persuasive social visualization for a real university class setting using social influence strategies of PT and to evaluate the effect of the strategies on students' activities. This research involves both quantitative and qualitative methods. The quantitative method used questionnaires in collecting data from students. Two surveys were carried out in this research among Biol 120 students. The first survey used a validated tool called "persuadability inventory" (PI) and adapted it to education. The survey was done to determine the susceptibility of the students to three social influence strategies of PT, to help the researcher gain insight on the implications of implementing the strategies and guide her in personalizing the strategies to the students. The second survey used a tool designed for evaluating the persuasive effect of systems. The survey was designed for evaluating the persuasiveness of the three versions of the persuasive system which operationalized the strategies employed in this research. It was carried out at the end of the persuasive system use by the students. Qualitative methods were employed to measure students' engagement using their activities with different learning support systems. Students' engagement measure was based on their learning activities on two systems: online MindTap and the SARA (persuasive system). The log data of their activities in the systems were used to estimate their engagement.

The research process comprises of six main stages.

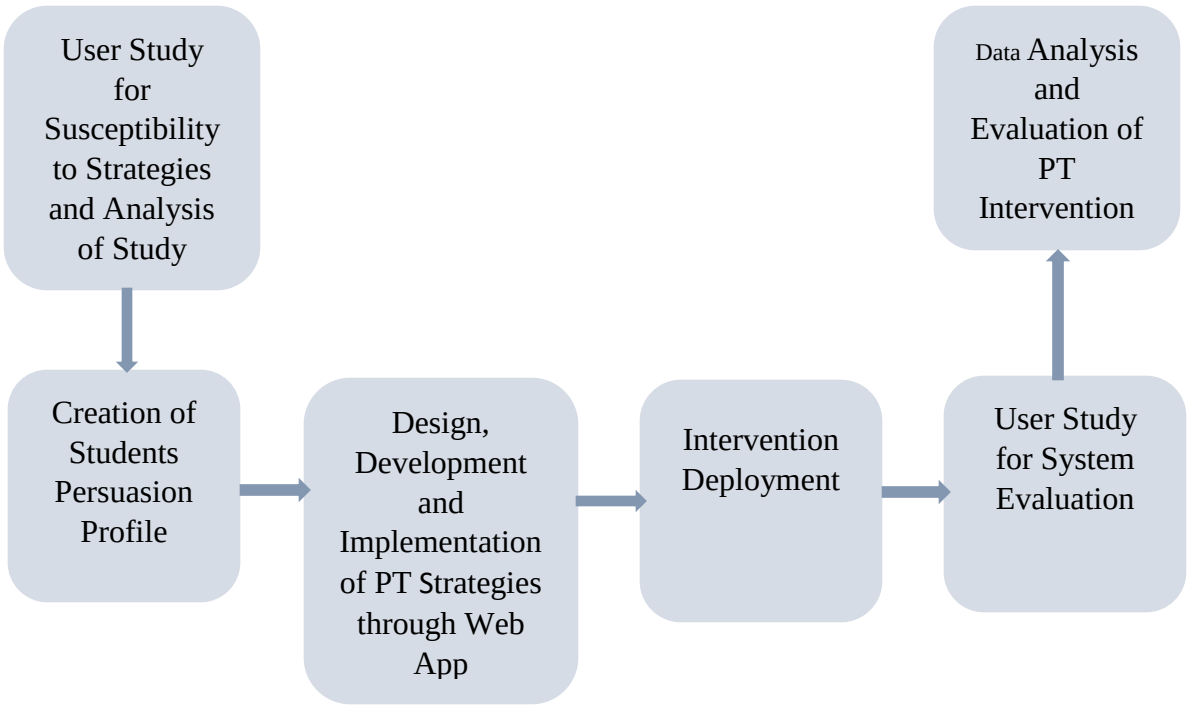

Figure 3. 1. Block Diagram of the Research Process

A user study for susceptibility to strategies: The first stage involves designing a questionnaire using a validated tool called Persuasive Inventory (PI) [14] to get data on the susceptibility of students to the three social influence strategies. This empirical study provides a means to measure the students' perception of the strategies.

Creation of Students Persuasion profile: For personalizing PT intervention to students, data from the first user study was analyzed and used to develop a persuasion profile for each student. This profile allows for classification and characterization of students based on their susceptibility to the three different persuasive strategies. The persuasive system operationalizes the strategies as system versions and uses the resulting classification in tailoring the system versions to the students. Classification details are in shown in chapter four.

Design, Development, and Implementation of PT Strategies in Web Application: This stage involves the determination of appropriate persuasive design techniques from literature and the actualization of the strategies in PT design using students' assessment grades.

Intervention Deployment: This process involves integrating the persuasive system with SARA, tailoring the three versions of the persuasive system to different groups of students based on their classification, and carrying out the actual experiment using the persuasive system.

User Study for System Evaluation: In this stage user study was carried out among the students that used the persuasive system to determine the system persuasiveness of the strategies implemented.

Data Analysis and Evaluation of PT Intervention: This final stage investigated the effectiveness of the persuasive system at motivating students for active engagement in their learning activities. Students' activities logs in various learning systems and their rating of the persuasive system were used for analysis.

3.3 Research Decisions

Based on this research context, I decided that adding a motivational social visualization to the students' learning environment will be a good approach to influence students towards active engagement in their learning activities. The persuasive social visualization builds on three social influence strategies (social comparison, social learning, and competition) of PT. Previous research on social visualization [37, 93, 98] has established that it is an effective means which can be used to increase a desired activity performance. Also, persuasive visualization has been shown to be effective in influencing people to bring about the desired change of attitude and/or behaviour [46, 58] in various domains such as e-commerce [91], physical activity [36] and health [75, 79]. However, following Tom Erickson's recommendations for the design of social visualization [31], all existing approaches have used a "one-size-fits-all" approach, showing the same social visualization to every user. In the area of PT, research [55, 74] has established that personalizing the persuasive strategies to users' preferences lead to a better outcome than using non-personalized strategies. Therefore, this thesis proposes a tailored social visualization to each individual student's preferred social influence strategy of PT.

Social Influence Strategies of PT employed in this Research

There are many persuasive strategies in existence nowadays, which have been employed in PT designs to bring about the desired behaviour and attitude change. Socially-oriented strategies as a class of persuasive strategies have been shown to be effective at motivating people for attitudinal and behaviour change when employed in PT design. They recognize the fact that humans are socially-driven and thus, our feelings, behaviour or opinion is affected by that of others (social influence). According to Fogg [35], people recognize computers as social actors because they

respond socially to computer software. Hence, computer software employs social influence principles for motivating and persuading users. Based on that Fogg advocates that computers can adopt social roles (such as teacher, doctor, teammate, pet, opponent, guide) to influence users.

Social influence [42] describes attitudinal or behavioural changes as a result of influence by other people which may be intentional or unintentional. Social influence strategies change people's opinion or attitude by using other people who are performing the desired behaviour as a role model for the target behaviour change. PT designers select strategies for use based on the problem they are trying to solve. In this section, I present an overview of three social influence strategies employed in this research in the context of persuasive technology in education (PTE).

Social Comparison is the natural drive to compare oneself with others to evaluate how one is faring relative to others. Its implementation in persuasive systems involves providing users with a means to view and compare their performance or behaviours with those of similar other users. Normally, students like comparing their grades with those of their friends and course mates. According to social comparison theory [32], people evaluate themselves by comparing themselves to similar others. This comparison could be an upward or downward social comparison. The upward social comparison is normally used for self-improvement as people compare themselves to similar others who are performing well on the specified task. The downward social comparison is used by people to raise self-worth as they compare themselves to other people, they performed better than [32]. The social comparison was used by Buunk et al. [15] in the classroom among 609 students in a secondary school to compare grades and motivate behaviour change. They found that students are often inclined to the upward comparison than downward comparison. Similarly, Dijkstra et al. [27], reviewed research on social comparison processes in the classroom using these themes: social comparison purposes, social comparison scopes, the direction of social comparison, and social comparison significances. They found that pupils usually use upward comparison when comparing their performance.

Social Learning strategy derived from Bandura's Social Learning theory involves people learning by observing what others have done or are doing [10]. The theory defines learning as a cognitive process and states that people learn through observation of others performing the target behaviours. Social learning also refers to Consensus or Social Proof [71, 91]. In persuasive technology, social

learning implementations often involve enlightening users about what similar other successful people in a target behaviour have done [52]. According to Oduor et al., the design feature of social learning software allows users to visualize others working on a similar goal and provide users with a means to view the progress of their peers [70]. In social learning, there is no obvious comparison or competition. The user does not have to be involved in the behaviour to learn, the user can learn through observation, imitation, and modelling.

Competition is the natural drive or intrinsic motivation exhibited by humans to outperform one another by taking a certain course of action. In PT design, the competition strategy provides opportunities for users to view their position on a leaderboard by showing their position relative to others. According to Oinas-Kukkonen et al. [71], the human's intrinsic motivation to outperform one another drive them to perform specific behaviours. Therefore, competition encourages users to change behaviour and attitude by tapping into the human natural drive to compete. Implementing competition in persuasive technology often involves people competing with either the persuasive system or against another human using the mechanism provided by the system. In persuasive applications, leaderboards which allow users to compare their scores and the score of other users to motivate them and increase their performance of the target behaviour is the most commonly used implementation of the competition strategy [91].

Table 3.1 shows the description of the strategies employed in this work and their implementations.

Table 3.1. Persuasive System Design Principles implemented, adapted from [71].

Social Support		
Strategies	**Example Requirement**	**Research Implementation**
Social comparison: System users will have a greater motivation to perform the target behaviour if they can compare their performance with the performance of others.	The system should provide means for users to compare their performance with the performance of other users.	The system provides the students with a means to compare their performance in a course with the performance of other students who did well in the same course (upward comparison). Grades are the bases for comparison.

Competition: A system can motivate users to adopt a target attitude or behaviour by leveraging human beings' natural drive to compete.	The system should provide a means for competing with other users.	The system uses a leaderboard to provide students with a means to compete with each other in respect to their grades to motivate them in engaging more in their learning activities.
Social learning: A person will be more motivated to perform a target behaviour if he or she can use a system to observe others performing the behaviour.	The system should provide a means for the user to observe the outcome of other users who are performing the target behaviours.	The system provides the outcome of the behaviour, showing the aggregate grade ranges for each assessment and the number of students that have each grade range.
Primary Task Support		
Personalization: A system that offers personalized content or services has a greater capability to persuade.	The system should offer personalized content and services to its users.	The system personalizes the social influence strategies to each user, using the user's susceptibility to the strategies (persuasion profile).

3.4 Data Collection Methods Used

Participants for this study were undergraduate students of the University of Saskatchewan taking Biol 120 during the winter term 2018. All the participants (students) were at least 16 years old. Before the main study, a pilot study was conducted to test the validity of our study instruments. For the pilot study, I recruited nine random students from the same university.

Two methods of data collection used in this research were: questionnaire and computer application log files.

Questionnaire: Is a research instrument for gathering information from participants in a study. It consists of a series of questions needed to collect information about a topic and can be paper-based or online-based. This research involved the administration of two online-based surveys. Easy access and availability to participants were the motivating factors for the choice of using an online-based questionnaire. Two validated tools were employed in the surveys to ensure the validity of the questions at measuring the intended quantities and adequate interpretation of measured outcomes.

Computer application logs: In computing, application logs contain activities or events recorded from the use of the application on a computer system. It usually contains information about the users and the activities they perform with the application. Two applications log files used in this research were online MindTap and persuasive system (SARA) log files. The download of these application logs took place before and after the persuasive system use.

3.5 System Persuasiveness and Engagement Measures

To measure the experience of different groups of students with the versions of the persuasive system used over the course of six weeks, I used a system exit survey. The survey is simply an empirically validated tool with four questions which many researchers in the area of PT use in evaluating their system design. The questions were measured using participant agreement with a 7-point Likert scale ranging from "1 = Strongly disagree" to "7 = Strongly agree".

To determine the impact of the persuasive intervention in respect of the students' engagement in their learning activities, I decided to measure engagement in their online MindTap through the number of logins, time spent on the system, and engagement score and also to measure their activities, interactions and events in the persuasive system (SARA) to determine engagement. The two systems; online MindTap and persuasive system contain each students' usage log data before and during the intervention.

3.6 Research Questions

This thesis will test the following broad hypotheses:

H1: *Socially-Oriented PT strategies will positively impact students' engagement in their learning activities.*

H2: *Other factors being equal, the social comparison strategy will motivate students to engage more in learning than the social learning strategy or the competition strategy.* The basis for this hypothesis was educational research [15, 27] which shows that students prefer an upward social comparison when it comes to their academic performance comparison.

H3: *Personalizing the social influence strategies employed in persuasive technology design will increase their effectiveness at motivating students to engage more in learning activities.*

H4: *Students will react positively to socially-oriented PT intervention.*

In the process the following research questions will be answered:

RQ 1: How do the students perceive the three versions of the persuasive system?

RQ 2: Does tailoring persuasive systems increase the perceived persuasiveness of the system?

RQ 3: Is there a difference in the perceived persuasiveness of the three social influence strategies overall?

RQ 4: Does the persuasive system lead to deeper learning engagement overall?

RQ 5: Does any of the strategies lead to more students' engagement than the others?

RQ 6: Is there a difference in engagement between the tailored and non-tailored intervention condition?

CHAPTER 4
DISCOVERING STUDENTS' PERSUASION PROFILES

To design an effective persuasive technology requires an investigation of the persuasive strategies that appeal to the target users. Understanding users' preferences for the strategies help PT designers in making informed decisions on the requirements and implications of their design. Some of the decisions are to determine whether specific strategies will be effective in motivating a particular user group and how to personalize PTs built with the strategies to users. For the personalization of persuasive technologies, a user persuasion model is developed to capture the susceptibility of each user to the spectrum of strategies chosen. This section focuses on the first user study performed to investigate the perception of users (students) to the strategies. The results of the user study will determine the appropriateness of the three strategies for the students. After determining the suitability of the strategies for the students, the results will help in forming each students persuasion profile and in classifying them according to their susceptibility to the three social influence strategies.

4.1 Study Design and Methods

The goal of the study is to determine the susceptibility of each of the participants (students) to three social influence strategies (social comparison, competition, and social learning) using a validated persuasive tool.

A tool for measuring susceptibility to these strategies was developed by Busch et al. [14] and is called persuadability inventory (PI). The PI includes a scale for these strategies: social comparison, competition, social learning, reward, and trustworthiness. The PI persuasive tool is used in this study because it is an empirically validated tool (gives an estimate of people's susceptibility to PT strategies) and many researchers have used it in their work. The tool consists of 6 items for measuring the *social comparison*; 5 items each for assessing the *competition* strategy and the *social learning* respectively. A questionnaire implementing the PI was slightly adapted to reflect the target domain, education. All questions were assessed using the participants' agreement to a 9-Likert scale ranging from "1 = Strongly Disagree" to "9 = Strongly Agree". The questionnaire also included questions on age range, gender, and student's id. Appendix C provides the full questionnaire.

4.2 Participants and Data Collection

Table 4.1 contains the participants' demographic information. Recruitment for the study was through announcements by the course lecturers and the sending of the survey link to the students. Participation in the study was voluntary. All participants were at least 16 years of age. To eliminate bias in the questions ordering, I used page randomization functionality provided by FluidSurvey, a survey software endorsed by the University of Saskatchewan at the time of the study. It varies the presentation order of the questions for each participant. A total of 243 complete responses was received. The preparation of the responses for analysis reveals that the responses contain some outliers - responses with duplicate and/or invalid student id (nsid). After removing the outliers from the data, two hundred and twenty (220) valid responses from 152 female and 68 male students remained for further analysis. This study aimed at determining the suitability of the strategies for the student and building a persuasion profile for personalizing the persuasive system to participants (students).

Table 4.1. Demographic Information of Participants for persuasion profile study

Total Participants = 220	
Gender	Females (152, 69%) Males (68, 31%)
Age	16 - 24 (200, 91%) 25 - 34 (18, 8%) 35 - 44 (2, 1%)

4.3 Measurement Validation and Data Analysis

According to Busch et al., [14] the persuadability inventory gives an estimation of people's susceptibility to a specific persuasive strategy which designers of persuasive technology can use in identifying the most effective persuasive strategy to be used in designing PT for a particular user or user group. The steps taken to analyze the data are presented below.

The data analysis started with the validation of the study instrument. The validation and data analysis was performed with IBM's Statistical Package. The internal consistency (general agreement between the items that measure strategies) for the items in the responses was determined, to test the validity of the responses. Internal consistency usually measures the

correlation of items in Likert scale to ensure the reliability of their measurement. Normally, internal consistency is measured using Cronbach's Alpha (α). The Cronbach's Alpha for this study responses is $\alpha = 0.817$ which means that the responses were reliable. Each participant's average for the three strategies was computed. Kaiser-Meyer-Olkin (KMO) sampling adequacy was calculated to be 0.858 and it was above the recommended 0.6. Then the Bartlett Test of Sphericity was found to be significant at (χ^2 (55) = 1481.855, $p < 0.0001$). The sampling adequacy and the test of sphericity showed that the data was adequate for further analysis [57, 69]. After verifying the data's suitability, I calculated the overall means for each of the three strategies and validated the data for ANOVA assumptions. Next, I performed Repeated-Measure ANOVA (RM-ANOVA) and pairwise comparison using the strategies as the within-subjects' factor and gender as the between-subjects' factor to examine and compare the persuasiveness of the three strategies.

4.4 Results and Interpretation

This section presents the results of data analysis and the implication of the results.

4.4.1 Comparison of the Persuasiveness of the Strategies

The questionnaire for this study has sixteen questions for measuring the perceived persuasiveness of the three strategies. Five questions out of the sixteen questions measure the persuasiveness of the competition strategy, six questions measure the social comparison and the remaining five questions - the social learning strategy. To compute the persuasiveness of a strategy, I calculated each student's average rating of the items measuring the strategy and then computed the mean (persuasiveness) of the strategy using the students' averages. Figure 4.1 shows the overall perceived persuasiveness of the three strategies. Overall, all the strategies are perceived as persuasive, as each strategy has a mean rating which is greater than the neutral score of 4.5 ($p<.001$), as indicated by the horizontal line in Figure 4.1. The RM-ANOVA results show significant main effects of strategy type ($F_{1.63, 355.54} = 22.04$, $p < .000$) on persuasiveness. It means that there is a statistically significant difference between the persuasiveness of the strategies. The result of a Bonferonni-corrected pairwise comparison reveals that there is a significant difference between the persuasiveness of competition and social learning and also between social comparison and social learning, $p< 0.05$. There is no significant difference between the persuasiveness of competition and social comparison. In general, competition ($M = 5.615$) and social comparison

(M = 5.560) are the most persuasive, significantly different from social learning (M = 5.029), where M represents the mean of each strategy.

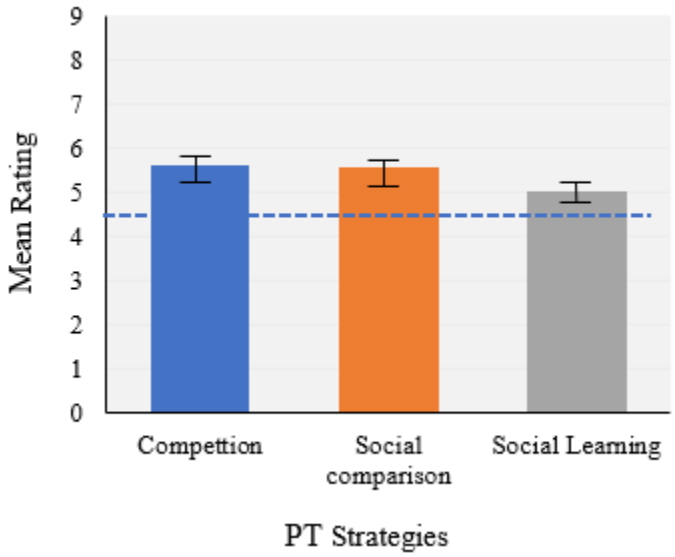

Figure 4.1. Mean rating of the strategies showing their overall persuasiveness

4.4.2 Between-Group Analysis: Gender Differences

The results of the between-group analysis demonstrated that there was no significant main effect of gender on the persuasiveness of the strategies. ($F_{1, 218} = 1.048$, $p = .307$). This means that the strategies are perceived equally by female and male students. Figure 4.2 shows the persuasiveness of the strategies based on gender. The groups (male or female) mean for the three strategies are Competition (Male (M=5.852), Female (M=5.379)), Social Comparison (Male (M=5.585), Female (M=5.535) and Social Learning (Male (M=5.038), Female (M=5.02). This shows that the strategies can be applied generally in education without considering gender difference.

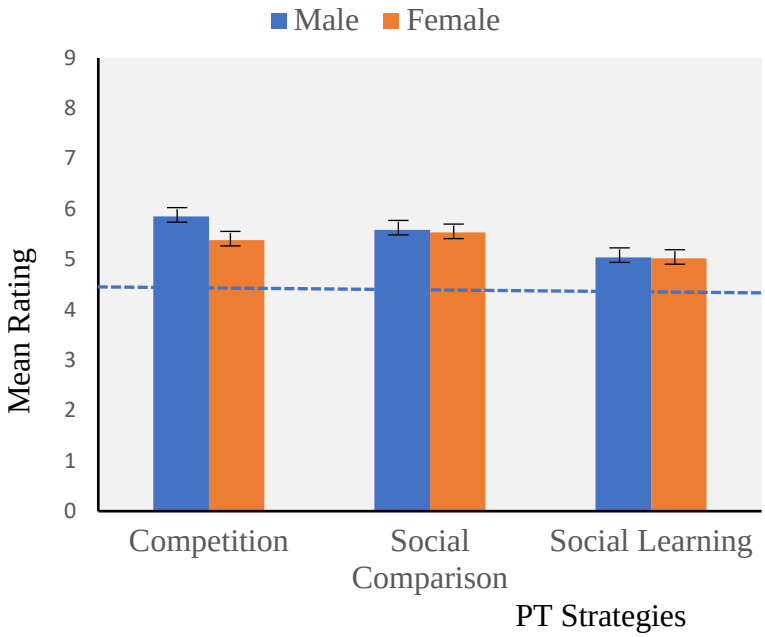

Figure 4.2. Means of the Three Strategies Paired by Gender

4.4.3 Participants Susceptibility to the Three Social Influence Strategies

Table 4.2 shows that 51% of the students are susceptible to all three strategies, 15% are susceptible to social comparison and competition, 9% are susceptible to social comparison and social learning, 4% are susceptible to social learning and competition, 5% are susceptible to competition only, 3% are susceptible to social comparison only, 1% are susceptible to social learning only, and 12% are not susceptible to any of the three strategies. The results show that the majority (88%) of the students could be persuaded using the three social influence strategies of PT.

Table 4.2. Susceptibility of the Participants to the three Social Influence Strategies of PT

Strategies	**Number of Participants**	**Percentage of Students (%)**
Social comparison - Social Learning - Competition	112	51
Social Comparison - Social Learning	20	9
Social Comparison - Competition	34	15
Social Learning - Competition	9	4
Competition	10	5
Social Comparison	6	3
Social Learning	3	1
Non-Susceptible	26	12

4.4.4 Discussion

Determining the applicability of PT strategies to a particular user group is an important step prior to PT design. Hence, implementing appropriate strategies in PT design increases its efficacy to achieve the intended objective. This study examined students' susceptibility to three social influence strategies. The results from the analysis demonstrate that the strategies are effective tools which can be employed to influence students' learning behaviour positively. Hence, most of the students rated some of the strategies as persuasive. It suggests that the implementation of the strategies in persuasive applications will encourage students to improve their learning behaviour. In general, there is no significant effect of gender on the persuasiveness of strategies by the students. It implies that the administration of educational systems designed with these strategies will create the same persuasive effect in both male and female students. Therefore, in creating students persuasion profile, I did not consider the gender of the student, but only considered the student's susceptibility to the three strategies. Following Busch et al. [14], *"participants having higher scores in one or more of the scales are expected to be more susceptible to these specific persuasive strategies (p.36).*" However, some students are susceptible to all the three strategies, as Table 4.2 shows. This means that any of the three strategies can motivate them to achieve a specific goal. The level of motivation each strategy provides depends on the participant's preference for that strategy. Hence, I considered participants' highest preference for any of the strategies in their persuasion profile. Table 4.3 shows participants preferences based on the strategy that motivates them the most. The table reveals that 38% of the students had competition as their highest preferred strategy, 30% had social comparison, 20% had social learning, and 12% were not susceptible to any of the strategies. This result indicates that the preference for competition (38%) is the highest, followed by social comparison (30%), and social learning (20%) is the least.

Table 4.3. Persuasion Profile of Participants based on their Highest Preferred Strategy

Strategies	**Number of Students**	**Percentage of Students**
Competition	84	38%
Social Comparison	65	30%
Social Learning	45	20%
Non-Susceptible	26	12%

Having established the appropriateness of the strategies for the students using this study, I decided to operationalize the strategies in an actual persuasive system to evaluate their effectiveness at motivating students to improve in learning activities.

CHAPTER 5
PERSUASIVE SYSTEM DESIGN AND TESTING

This chapter describes the design of the persuasive system. The system design draws from the persuasive system design (PSD) model by Oinas-Kukonnen (2010), specifically, it operationalizes three social influence persuasive strategies (social comparison, social learning, and competition) in the form of visualization using students' assessment grades. The visualizations are meant to motivate students to engage more in online learning activities. By visualizing the performance of other students in their coursework, the system will be able to allow students to monitor their academic progress relative to their peers, estimate their performance and the area they need to study more. Therefore, evidence-based data of students' grades and social influence are combined in the design to promote students' engagement in their learning activities and hence, improve learning outcome.

I developed three versions of a persuasive system, one for students who are motivated by social comparison, the second one for students persuaded by social learning, and the third for students inspired by competition. Although the content of the three versions uses students' grades, their design and implementation differ in the employed persuasive strategies. Thus, each student's experience depends on the version of the persuasive system that the student gets.

5.1 Design Rationale

Because of the need to develop the persuasive intervention in a field experiment (in a university course), the choice of platform for the persuasive system was my first design decision. The system has to be always available and accessible to the students in a familiar environment. Thus, I resolved to develop a web application and integrate it with the students' learning management system. In this way, students needed not to install additional software or waste their time to link the web application.

Following the choice to develop a web application, was the decision on the development platform. There are many web application platforms available such as Django, Ruby on Rails, Angular.js, ember.js, CakePHP, Java, etc. After considering the pros and cons of these platforms and how web application built on them could be integrated with the existing learning management system that the students are already using, I decided to choose Java as my development platform.

Java applications are platform-independent, robust, easily scalable and have enhanced security features. The Java language has multithreading and network support. Its extensive use for enterprise, embedded, and network application is because of its stability. Java class libraries permit cross-platform development. Its versions tolerate forward capabilities. Because of Java cross-platform, applications developed with it integrate easily with other applications. Having chosen the development platform, I decided to use Html5 (Hyper Text Markup Language), CSS (Cascading Style Sheet), and JavaScript as the front-end technologies for designing the visualizations because of the following: every web browser supports them, they have faster loading time, they permit execution of dynamic content on a web page, and they build beautiful and dynamic visualization.

Next, I considered the issue of security and students' privacy as I use individual student's information to develop the application for social comparison and competition. Social learning also uses students' information but in an aggregated form. Students log in to the learning management system with their student identification number (Id). To solve the privacy problem, I use a pseudonymised student Id to display students' grades and points except for the logged-in student. For the logged-in student (who views the visualization), the student's actual Id and name are shown so that he or she can identify his or her position in comparison with the others.

5.2 Persuasive System Design

The persuasive system design follows a client-server architecture implemented using Java Enterprise technology. The implementation uses the Model-View-Controller pattern in separating its components. It comprises of the enterprise application-tier and the client-tier.

The persuasive system components were implemented using Java Web Application running on tomcat web application server. The enterprise application-tier component connects to a MySQL database containing students' credentials and their course details. It has the following main modules: Database, IdAnonymization, SocialComparison, SocialLearning, and Competition module. The database module handles the application connection to an MYSQL database, retrieving of the students' credentials and assessments grades for Biol 120, and saving of students' feedback to an MYSQL database. The IdAnonymization module applies pseudonymization (a process that replaces data record with an artificial identifier) techniques to convert students' Ids. The SocialComparison module retrieves assessment grades from the database module, calculates

the class average for each assessment (assignment, quizzes, lab exam, and midterm), computes each student average on all the assessments and sorts the students' records based on their score. Finally, it compares the logged-in student's average with that of the classmates and returns five students' records who are performing better than the logged-in student. However, if the logged-in student is the best in the class, it will return five students' records whose average are close to that of the logged-in student. Then the IdAnonymization module is invoked to pseudonymize the Id of the five selected students (however, it retains the actual id of the logged-in student). The SocialLearning module retrieves students' assessments grades for Biol 120 from Database module and groups them into six different grade ranges: 90-100, 80- 89.9, 70-79.9, 60-69.9, 50-59.9, and less than 50. It then calculates the number of students belonging to each grade range for each of the assessments. Next, the Competition module obtains Biol 120 students' credentials and assessments grades from the Database module and computes each student point based on the weighted score for each of the assessments. The students' data are sorted based on their points and the top eleven students' records selected. If the logged-in student record is not among the top eleven records selected, her/his record will be used to substitute the eleventh student. Subsequently, the IdAnonymization module is invoked to pseudonymize the Id of the ten selected students while leaving the actual id of the logged-in student.

The client-tier (persuasive visualization) has three main components: social comparison visualization, social learning visualization, and competition visualization. The components provide students with an opportunity to know their academic stand for a course relative to their classmates.

5.3 Persuasive Visualization Design

This subsection presents a detailed explanation on the use of students' grades and social influence strategies (competition, social comparison, and social learning) to design and develop a persuasive visualization for encouraging students in active learning engagement.

The front-end of the web application operationalizes three social influence strategies; social comparison, social learning, and competition in designing the three versions of the persuasive visualization. These three social influence strategies were selected because persuasive technology research [75, 83, 91] has established their effectiveness at changing behaviour or attitude positively.

The visualization (in all three versions) is updated dynamically when students perform new assessments. Each visualization version provides students with an opportunity to send feedback on their feeling about their grade using three emojis: satisfied, surprised, and frustrated as shown in Figure 5.1, 5.2, and 5.3.

5.3.1 Social Comparison Version of the Persuasive Visualization

The Social Comparison version is shown in Figure 5.1. It uses an upward comparison strategy to make each student aware of their performance relative to others who are performing well in a particular course to motivate them towards a desirable learning outcome. The visualization uses a table and grouped barchart in displaying the information, which is a common visualization type and should be familiar to the students. The visualization displays the logged-in student (real name (Fidelia), real id (F123p), and grades in different assessments in the Biol 120), the class average for each assessment, and grades of five random students who have higher grades than the logged-in student. “Five random students” means that from the total number of students that performed better than the logged-in student, five students’ records are randomly selected and presented using their pseudonymized Ids. The visualization changes with subsequent assessments and gives the logged-in student an opportunity to compare (upward comparison) her assessments grades to those of her classmates and with the class average for each assessment. The display of five random other students’ grades gives a different combination of display patterns for each student, based on his/her grades. The number of other students that are displayed is limited to five to make it easier for the logged-in student to compare herself with the other students.

Hi Fidelia,
See how you compare to your peers.

ID	LabExam	Midterm
ClassAve	69	65
F123p	80	90
jm	84	88
ms	84	90
rd	92	78
sc	88	85
tk	92	80

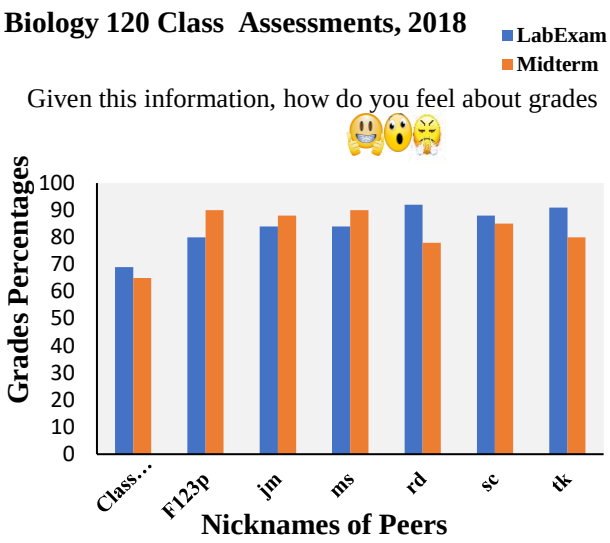

Figure 5.1. A display of the logged-in student's grades and grades of five random students with anonymized id who have higher grades than the target student (upward Social Comparison)

5.3.2 Social Learning Version of the Persuasive Visualization

This version employs the social learning strategy in enlightening students about the class performance in each assessment in Biol 120. One of the problems in the university system is that it does not provide students with opportunities to learn from each others' course experience to improve their success. According to social learning theory [10], people learn by observing others (in this case observing others performance). Observational 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 motivate them to engage in more learning activities. All the students doing the course were grouped based on their grade ranges. The visualization as shown in Figure 5.2 is essentially a grade distribution for the class assessments, presenting the number of students belonging to different grade ranges for each assessment. Unlike the social comparison visualization, which shows the logged-in student's grades and that of other students, the social learning visualization does not show the logged-in student her stand against her peers but provides her information about the progress of everybody in the class so that she can adjust her learning behaviour accordingly. The grade distribution (performance) will act as a benchmark that the students can use to evaluate their academic progress. The hope is that a realistic

evaluation of students' performance would motivate them to work harder to improve their learning outcome.

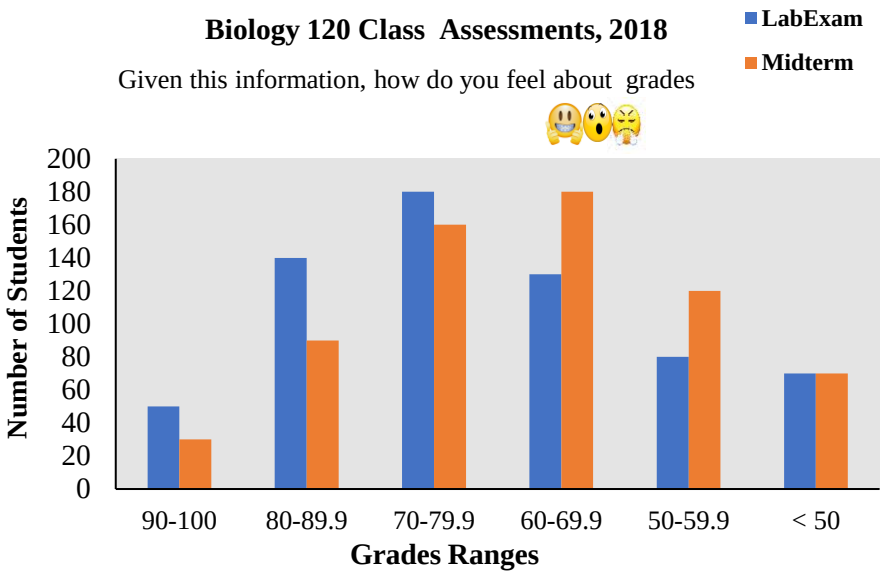

Figure 5.2. A display of grade ranges and the number of students that has each range in a course (Social Learning)

5.3.3 Competition Version of the Persuasive Visualization

Research has shown that some people tend to perform better when they are encouraged to compete [49]. To create a competitive situation, the competition strategy visualization uses a leaderboard to display and rank students based on their performance (see Figure 5.3). The visualization displays eleven students on the leaderboard, which includes the top ten students and the logged-in student, sorted in decreasing order of their grades. The leaderboard also shows the logged-in student's position in the competition relative to other students in the leaderboard. The visualization shows the real student identity of the logged-in student to draw her attention to her position. Again, for security and privacy reasons, the other students' identities are disguised with pseudonyms. The leaderboard is programmed to automatically update itself using students' subsequent assessments grades dynamically retrieved from the database. In Figure 5.3, the logged-in student is not among the ten top students in the class. Therefore, she automatically becomes the eleventh person on the leaderboard. The actual rank of the logged-in student in the whole class is not shown to avoid a possible demotivating effect.

Hi, Fidelia

Biology 120 Class Leaderboard, 2018

*Points total is calculated from your weighted assessments in the class so far.
Given this information, how do you feel about your ranking?

Rank	Nickname	Points
1	af	372
2	kb	363
3	sk	359
4	ap	354
5	jj	352
6	hn	351
7	am	349
8	gs	348
9	bc	347
10	cs	346
11	Fidelia	338

Figure 5.3. A display of students' ranks based on their performance (Competition)

In a competitive environment, people try their best to be the winner or to get higher points than their fellow competitors and this drives them to put more effort into the competitive task. The competition visualization informed the students that their points are calculated based on their assessments' performance. Therefore, for their point to increase they need to have an improved grade in their assessments. For example, in Figure 5.4, the logged-in student's point increased as a result of improved performance in her next assessment. Then she becomes among the top ten students and is automatically ranked as the second person on the Leaderboard based on her point.

Hi, Fidelia

Biology 120 Class Leaderboard, 2018

*Points total is calculated from your weighted assessments in the class so far.
Given this information, how do you feel about your ranking?

Rank	Nickname	Points
1	af	380
2	Fidelia	370
3	jj	369
4	ap	368
5	sk	364
6	kb	356
7	am	355
8	hn	354
9	gs	353
10	cs	352
11	bc	350

Figure 5.4. A display of students' ranks based on their performance (Competition).

5.4 Integration of the Persuasive System into the Learning Management System (LMS)

Biol 120 students involved in this research use the LMS for communications related to the course. The LMS has the SARA agent (presented in Chapter 3) integrated into it. The SARA agent sends weekly course-based messages to students via the LMS. The messages are personalized based on each student course learning needs. The persuasive visualization communicates with the LMS as shown in Figure 5.5. The LMS displays messages to the students along with the persuasive visualization tailored (or not) to their persuasive type. Students' feedback on the visualization is collected and stored in a database.

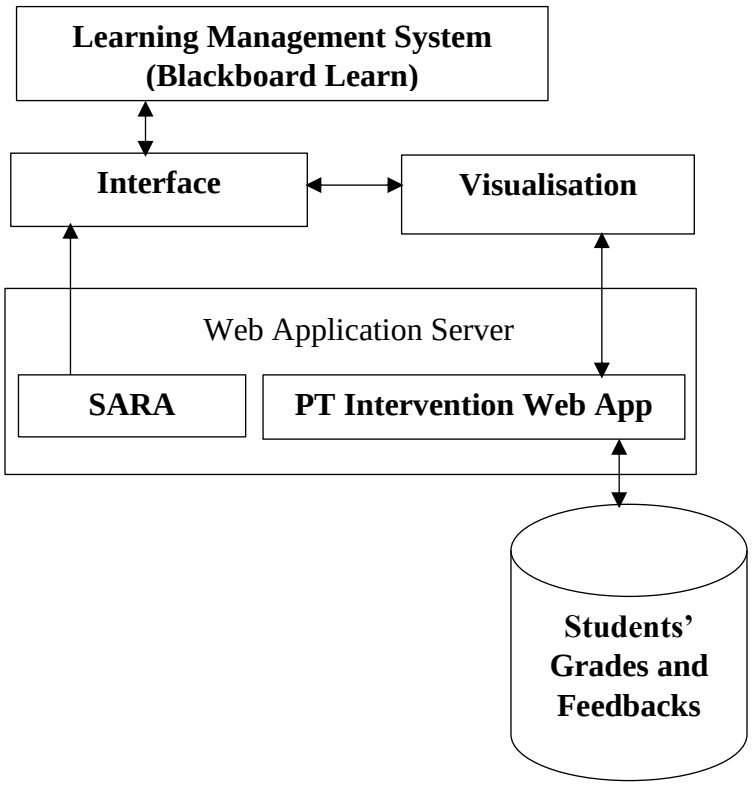

Figure 5.5. Block Diagram showing how the PT intervention is integrated into LMS

5.5 Preliminary Evaluation of the System

A pilot study was conducted to get initial user feedback on the persuasiveness of the designed system. I recruited 9 students from the University of Saskatchewan. The Busch et al. [14] PI tool was adapted to measure the students' susceptibility to the three social influence strategies before the introduction of the system to them. The participants were presented with the three versions of the system representing social comparison, social learning, and competition, varying the order of presentation to reduce bias. The system versions were accessed one after the other. After each version usage, the participants filled in a questionnaire adapted from the Orji et al. [76] persuasive tool. Other PT researchers [76, 79] have used this tool in measuring the persuasiveness of their system. The persuasive tool comprises of four questions: "*The system would influence me*"; "*The system would be convincing*"; "*The system would be personally relevant to me"; "The system would make me reconsider my studying habits*". The questions were measured using the participants' agreement with a 7-point Likert scale ranging from "1 = Strongly Disagree" to "7 = Strongly Agree".

5.5.1 Results and Discussions

Table 5.1 shows the susceptibility of the participants measured using the Busch et al. [14] persuasive inventory. P1 to P9 represents the nine participants involved in the study and CMPT, SCMPR and SLEARN represent the participants perceived persuasiveness for each of the strategies Competition, Social Comparison, and Social Learning respectively. The Busch et al. [14] PI tool has a neutral score of 4.5 because it is a 9-point Likert scale. From the persuasion profile in Table 5.1, four (4) participants (P2, P3, P6, P9) scored high in all the three strategies (their scores were above the neutral score), four (4) participants (P1, P5, P7, P8) also scored high in two of the strategies, and one participant (P4) scored high in one strategy. Scores above the neutral score in any of the strategies show that those strategies will persuade the participant. For each of the participants, the strategy that the participant has the highest score becomes the most preferred strategy by this participant.

Table 5.1. Showing individual susceptibility to social influence strategies using the PI

	CMPT	SCMPR	SLEARN
P1	7.6	6.50	4
P2	5	7.00	5.6
P3	7	5.83	5.4
P4	2.6	2.83	4.8
P5	8.8	5.50	2
P6	6.4	5.67	5.2
P7	4.2	6.17	5.2
P8	7	3.33	5.4
P9	8.4	7.67	5.4

CMPT	Competition Strategy
SCMPR	Social Comparison Strategy
SLEARN	Social Learning Strategy

Highlighted numbers correspond to each participant's susceptibility profile, i.e. the strategy with the highest score for this participant.

The susceptibility score in Table 5.1 shows that P1, P3, P5, P6, P8, and P9 will be motivated more using the competition strategy. P2 and P7 will be motivated more using the social comparison strategy while P4 will be motivated using the social learning strategy.

Table 5.2. Showing the participants perceived persuasiveness of the system measured using Orji et al. [76] persuasive tool

	CMPT	SCMPR	SLEARN
P1	3.5	**5**	2.75
P2	3	6.75	5.75
P3	5.75	**7**	5
P4	3.5	3.5	4.5
P5	5	**5.75**	4
P6	5.75	5.25	5.5
P7	5.5	7	6.5
P8	5.75	5.75	4.75
P9	7	5.75	6.5

CMPT	Competition Strategy
SCMPR	Social Comparison Strategy
SLEARN	Social Learning Strategy

Highlighted numbers show participants for whom their susceptibility score corresponds to their system persuasiveness score; the red numbers show participants whose susceptibility score differs from their persuasive score.

The results of the persuasive system evaluation study with 9 students show the efficacy of the system for motivating students to engage more in their learning activity overall. In general, all the participants rated the individual strategies as persuasive as regard to the persuasive system's ability to motivate students for more engagement in their learning activities. All the persuasiveness scores were either greater than or equal to the average persuasiveness score of 3.5 except for participants 1 and 2 (P1 and P2) who rated social learning and competition version of the persuasive system as below average in persuasiveness, respectively. (As shown in Table 5.2, P1 gave social learning a 2.5 score while P2 gave the competition a 3.0 score and the average score is 3.5 on a 7 point-Likert scale.) It means that most of our participants perceived the system versions as persuasive overall, irrespective of whichever persuasive strategy employed in the design. In respect of personalizing the system, the results show that most of the participants responded more positively to those visualizations that implemented the strategy corresponding to their profile (i.e. their individual susceptibility). More specifically, 6 out of 9 of the participants rated higher the persuasiveness of the tailored version that corresponds to their persuasion profile as predicted using the persuasive inventory prior to the persuasive system usage. It means that personalizing the system using the individual's persuasion profile would increase the efficacy of the system to motivate students to engage more in their learning activities. Figure 5.6 shows the persuasiveness of the persuasive system by strategy (version) and by individual participants. The Horizontal line indicates the mean

rating of 3.5, the bars highlighted with red correspond to the three participants whose strategy susceptibility score according to Table 5.2 does not correspond to their perceived system persuasiveness score.

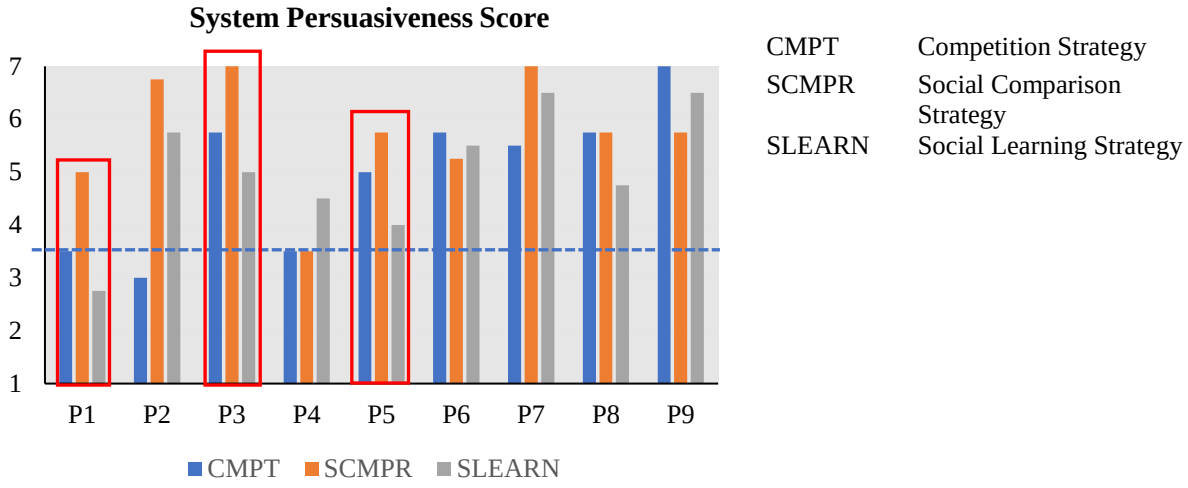

Figure 5.6. The system persuasiveness by strategy and participants

The prediction of susceptibility score proved to be true for all the participants except for P1, P3, and P5 who rated as the most persuasive the system versions designed using strategies that correspond to their second-best strategy in their susceptibility profile. One reason may be that participants used the system for a short time and may not have real experience of how the system works in real-life when applied in actual class and course setting.

5.5.2 Limitations

One limitation of this work is the small number of participants used in the preliminary evaluation of the system. Nine participants are a too small group to obtain any significant and generalizable results. Another limitation is that participants used the system once and may not have gotten a detailed experience of how the system works and the difference between the versions. Third, the participants used the system out of context, i.e. not applied to any course that they are involved in, and that may have influenced their experience and ratings.

CHAPTER 6
PERSUASIVE SYSTEM: FIELD STUDY

The previous three chapters presented the educational context and the main approach proposed in this thesis for using personalized persuasive visualizations to encourage students' engagement in learning activities, the students' profiling according to three social influence persuasive strategies, the persuasive system design and the pilot study showing the promise of the personalized persuasive approach. This chapter presents the full implementation of the system in a university class and the experimental design of a field study to evaluate the effectiveness of the proposed approach.

The implementation of this system involves all the students taking BIOL 120 in the winter term 2018 at the University of Saskatchewan. A total of 643 students participated in the field study. One hundred and seventy-six (176) out of the 643 participated in the persuasive profiling.

6.1 The Persuasive System Implementation Strategy (Experimental Setup)

Considering that the study was taking place in a real learning environment, care had to be exercised in the students' assignment to the different persuasive visualization versions, in order not to disadvantage any students.

Therefore, the design of the experiment followed two main goals:

1) Research experiment design: to test the hypotheses, students' groups had to be composed of students with homogeneous persuasive type (susceptibility to one of the three strategies) so that a Latin-square experiment design or a variation of it could be applied. This would allow testing tailored versus non-tailored and tailored versus counter-tailored persuasion for each persuasive type group. Chapter four presented the students' persuasion profiles used for their grouping and how they were determined.

2) Maintaining the integrity of the learning environment: since this is a field experiment, in a "life" university class, any intervention that could have a negative effect on the success of the student (demotivation, discouragement, etc.) is not ethically permissible. Therefore, the formation of students' groups needed to be done with special care to avoid putting students who might be vulnerable to an experimental condition that may have a negative effect on their learning, motivation for learning, or psychological state in general. Special care was required for the

competition grouping since previous research [80] indicates that some students may be competition averse and exposing them to competition may discourage them, especially if they are not doing well in the class. For this reason, I employed a gamification construct called "game balancing" in addition to the persuadability of participants to competition strategy. Game balancing defines a concept in game design use to make games enjoyable and motivating to users. It is normally used in competitive games to enhance its ability to achieve a desired objective. For example, Adams et al. [6] demonstrate that people will be motivated to participate in competitive activities if they have the opportunity to win. Also, Cechanowicz et al. [16] in their research with 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 [16, 22, 92] has shown that grouping people with equal strength and ability in competition make it more enjoyable and desirable. In order to balance the ability of participants in the competition group, students predicted grades were employed.

Therefore, for the *competition grouping*, two factors were considered in combination: the students' preference for the *competition strategy* and their predicted grades in the course. The grade prediction is part of the SARA system. It uses a linear regression model involving students' high school cumulative average, high school biology grade, students' self-efficacy, and high school status in generating the students' predicted grade for Biol 120.

Kappan and Orji [51] 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, only those who have the highest susceptibility to competition strategy and have top grades (75% and above in their biology predicted grades) were involved in this group.

The students with the highest susceptibility to competition but with predicted grades less than 75% were assigned to their second-most preferred strategy from their persuasion profile. Most of them had *social comparison* as their second preference, which is not surprising since research [76] has established that competition and comparison are interrelated because social comparison is a necessary step (though not sufficient) for competition.

I also assigned to the competition group some of the students who had low persuadability preference in all three constructs but with high predicted grades (80% and above). Regarding the possible negative effects of competition, I expected that these would be mitigated to a large extent, since seeing that they are among the top students in the class this would encourage these students.

The groups under the *social comparison* and *social learning* conditions comprised of the participants with the highest susceptibility to the corresponding strategy (tailored conditions).

The remaining students with low susceptibility to all three constructs were randomly assigned to social comparison and social learning. They serve as a counter-tailored group (students who were not susceptible to any of the three strategies but participated in the persuasive intervention).

Moreover, I grouped the students who did not complete the persuasive inventory (PI) survey as follows: some students with high predicted grades (80% and above) were randomly assigned to competition version (control competition), expecting that the students will be encouraged when they see that they are among the top students in the class. The remaining students were randomly assigned to the social comparison version (control social comparison), social learning version (control social learning), and to a "No Visualization" group (control base). These students might be assigned to a persuasive strategy group which is not personalized to their preferred strategy, so each of the three control groups had a "One-Size-Fits-all" system instead of a system tailored to their persuasion profile. These control groups will be used to compare the effect of tailoring the intervention for each of the system version. Also, they will help to determine the most effective strategy on average.

Finally, based on the above criteria, four experimental conditions of the persuasive system were used by the students. The conditions include social comparison, social learning group, competition, and No Visualization.

6.2 The Persuasive System Experiment

Before the start of this intervention, I downloaded and saved students' activities in their Biol 120 online learning system (MindTap) from the 1st week to the 7th week of winter term 2018. This data served as a baseline for comparison of the students' activities before and during the intervention. The intervention experiment was used to support and encourage students to engage actively in their learning activities. It gives students the opportunity to compare their grades, compete based on grades, or model their learning towards achieving improvement in performance. The intervention started in the 8th week (i.e. 26th February 2018), after the students had finished their midterm exam, and ended in the 13th week (i.e. 6th of April), the end of the term. During each week

of the intervention, the weekly activities of the students in the online system were downloaded and kept for analysis.

Based on the experimental condition, 36 students used the competition version of the persuasive system, 265 students used the social comparison version, 194 students used the social learning version, and 148 students did not use any of the versions of the persuasive system. Among the 643 students involved in this system implementation, only 176 students (those who participated in the user persuasive type study) got a version of the system with a visualization that was tailored to their persuasive type. From the students who got a tailored version: 21 got the competition version, 102 got the social comparison version, and 53 got the social learning version. The remaining 23 students who were not susceptible to any of the three strategies were randomly assigned to the strategies ("contra-tailored" group for each of the persuasive strategies). Table 6.1 presents the summary of students' assignments into experimental condition for each version of the persuasive system. The students that did not participate in the user persuasive type study (444 out of 643) were randomly assigned to the four groups (competition, social comparison, social learning, and No Visualization).

Table 6.1**.** Summary of the assignment of the persuasive system to different experimental condition of students

	Competition Version	**Social Comparison Version**	**Social Learning Version**	**No Visualization**
Tailored	21 Students with the highest score in Competition Scale and High predicted grades received this version.	102 Students with the highest score in social comparison scale and those in the competition strategy who did not meet the criteria but have Social Comparison as their second preferred strategy receive this version.	53 Students with the highest score in social learning scale and those in the competition strategy who did not meet the criteria but have Social Learning as their second preferred strategy receive this version.	

Contra-tailored (low PI score for all strategies, "immune")	1 Some students with low PI score on all three persuasive strategies and 80% predicted grade receive this version.	11 Some students with low PI score on all three persuasive strategies receive this version.	11 Some of the students with low PI score on all three persuasive strategies receive this version.	
Random (PI score unknown, "one size fits all")	14 Some students with a high score in predicted grade (80% and above) were randomly assigned this version.	152 Some of the students that did not participate in the preliminary survey were randomly assigned this version.	130 Some of the students that did not participate in the preliminary survey were randomly assigned this version.	148 Some of the students that did not participate in the preliminary survey were randomly assigned this version

According to literature, adapting persuasive strategies to users' preferences make them more effective in achieving the desired behaviour or attitude. And it also helps to avoid demotivating users. The effectiveness of personalizing this persuasive intervention to student's susceptibility will be determined by comparing the activities of students in the tailored and random group.

6.3 Demographic Information of Participants for the Persuasive Intervention

As discussed in chapter three, the participants for this study are Biol 120 students. Table 6.2 presents the demographic information of participants.

Table 6.2. Participants demographic information for the persuasive intervention

Total Participants = 643	
Gender	Females (397, 62%) Males (236, 37%) Unknown (10, 1%)
Age	16 - 24 (568, 88%) 25 - 34 (59, 9%) 35 - 44 (6, 1%) Above 45 (1, 1%) Unknown (9, 1%)

CHAPTER 7

PERSUASIVE SYSTEM EXPERIMENT DATA ANALYSIS

This chapter presents the results of data analysis done to determine the effect of the persuasive system on students' engagement in their learning activities. Specifically, it investigates whether the persuasive system is perceived as persuasive by the students and if it is effective at promoting engagement in learning activities. It also examines whether students who used the tailored system version engaged in more learning activities than those that used the non-tailored version, and which persuasive strategy was most engaging overall. To evaluate students' engagement, two data log files were used to determine changes in students' engagement in learning activities as a result of the persuasive system use:

1) The data log file from access to the persuasive system (containing the SARA agent and the persuasive visualization) and

2) The MindTap (the students' online e-book) data log file which shows students' access to the learning support system with exercises.

The number of student participants was 643, out of which 495 students used the persuasive system and 148 students were in the control group. The experiment ran for six weeks. At the end of the experiment, the students were asked to fill out an online questionnaire to rate the persuasive system and to give consent for their data to be used in analysis and for it to be linked to their student records. Among the 643 students in the experiment, 266 filled the system exit survey, and 228 gave their consent for the use of their data in the analysis. The persuasive system evaluation and data analysis in this research are based only on the data of the students who gave their consent. Table 7.1 below presents a summary of intervention type and experimental condition of students involved in this analysis.

Table 7.1. Summary of the experimental condition of students for data analysis

	Competition Version	**Social Comparison Version**	**Social Learning Version**	**No Visualization**
Tailored	15	62	19	
Contra-tailored	1	5	5	
Random (non-tailored)	5	38	43	35
Total	21	105	67	35

Among the students that used the tailored persuasive system version, 96 students gave consent for their data to be used in this analysis. For the non-tailored version, 86 students gave consent for use of their data in the analysis. For contra-tailored, 11 students and no visualization, 35 students.

7.1 Determining the Persuasive System Effects on Students' Engagement in Learning

This section presents an analysis of the students' data log files from two systems, the persuasive system, and the MindTap system.

The broad hypothesis of this research is that socially-oriented persuasive systems will motivate students to increase engagement in their learning activities and improve academic performance. To test the hypothesis, I defined the students' engagement in learning activities as different measurable activities in the two systems. The measures are objective (i.e. they are derived from students' activities on the systems).

The effect of the persuasive system on each student's engagement in learning activities was measured and aggregated based on students' group to enable comparison across the experimental condition.

7.1.1 Determining Persuasive System Effects on Students' Learning Engagement using MindTap System Data Log File

The online MindTap system, as explained in Chapter three, is a separate system that the students use to do exercises and learn. It is not directly connected to the persuasive system, hence the persuasive visualization is not directly visible to the students while using the MindTap. The expectation is that the visualization in the persuasive system that contains also the SARA personalize advices (SARA is not a subject of this thesis), will inspire students for deep engagement with the e-book (MindTap). Below, I describe the features that are measured to obtain information on students' engagement within the MindTap system.

Engagement in this system is measured weekly using:

- the number of logins in MindTap.
- time spent on the system
- engagement scores (This is also provided by the MindTap system log. The system calculates it based on time spent and activities completed on the system.

Prior to the introduction of the persuasive system, students have been using the MindTap system for their learning activities. The details of the MindTap system were explained in chapter three. For the time before the intervention, the students have access to the MindTap system, so their interactions with the system were used as a measure of engagement. As a result, students' engagement in this system was calculated based on the number of logins in MindTap, time spent on MindTap, and engagement score. The students used the MindTap system for seven weeks before the persuasive intervention was introduced. They continued to use the MindTap system during the six weeks of persuasive intervention usage. To get the engagement score before the intervention, the weekly average of students' number of logins, time spent on the system, and engagement score for the seven weeks were calculated. For the engagement score during the intervention, the weekly average of students' number of logins, time spent on the system, and engagement score for the six weeks were computed.

7.1.1.1 MindTap System Data Log File Analysis

Among the 228 students that consented for the use of their data in analysis, 20 students did not sign up for the use of online MindTap. As a result, the MindTap analysis was based on 208 students. The summary of the experimental condition of students for this analysis is shown in Table 7.2. Tailored has 91 students while non-tailored has 75 students. Contra-tailored has 10 students and No Visualization has 32 students.

Table 7.2. Summary of the experimental condition of students for MindTap data analysis

	Competition Version	**Social Comparison Version**	**Social Learning Version**	**No Visualization**
Tailored	14	59	18	
Contra-tailored	1	4	5	
Random (non-tailored	3	34	38	32
Total	18	97	61	32

To investigate whether there is a difference in the students' engagement with their online (MindTap) learning activities, I performed the following analysis.

1) One-way within-subject ANOVA to compare engagement before the introduction of persuasive visualizations intervention and during the intervention use.

2) Repeated-Measure MANOVA (RM-MANOVA) using time (before and during the study) as a within-subject factor and intervention type (tailored versus random) as a between-subject factor.
3) RM-MANOVA with time (before and during the study) as a within-subject factor and experimental condition that students belong to (competition, social comparison, and social learning) as a between-subject factor.
4) RM-MANOVA to compare engagement of the students that participated in the persuasive intervention (visualization group) and those that did not participate (control group) over time.

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

7.1.1.2 Results of Engagement Based on MindTap Log Data

All the analyzes performed with data log file from the MindTap system are presented in this section.

Change in Student Engagement on MindTap Over Time as a Result of the Persuasive System Introduction

The descriptive statistics on students' engagement over time show that there are differences in students' engagement before introducing the intervention and during the intervention as shown in Table 7.3. To evaluate the nature of the differences, one-way within-subject ANOVA was conducted to test the effect of the persuasive system on students' engagement in their learning activities, i.e whether there was a statistically significant change in students' learning engagement before intervention introduction and during intervention use. The engagement was assessed using a weekly average of the number of logins, time spent on the MindTap system, and engagement score on the system. The results show statistically significant difference on students' engagement in their learning activities for all the three measures: number of logins ($F_{1, 174} = 428.319$, $p = .0001$, $\eta^2 = .774$), time spent ($F_{1, 174} = 98.610$, $p = .0001$, $\eta^2 = .401$), and engagement score ($F_{1, 174}$

= 2499.862, p = .0001, η^2 = .944). Pairwise comparison result shows that the persuasive system promoted an increase in engagement for all the three measures, p < .0001.

Table 7.3. Descriptive statistics of learning engagement before and during intervention use

	Descriptive Statistics					
	Number of Logins (Count)		**Time Spent (Sec)**		**Engagement Score (Points)**	
	Mean	SD	Mean	SD	Mean	SD
Engagement before intervention introduction	19.79	11.145	6397.737	5708.71	22.638	4.322
Engagement during intervention use	169.56	97.667	34356.64	39349.91	177.599	39.796

The students were significantly more engaged in their online learning activity when using the persuasive system compared to before introducing the intervention, as can be seen in Figure 7.1. Analysis for comparing engagement of experimental condition with control group will help in confirming if the persuasive system promoted students' engagement.

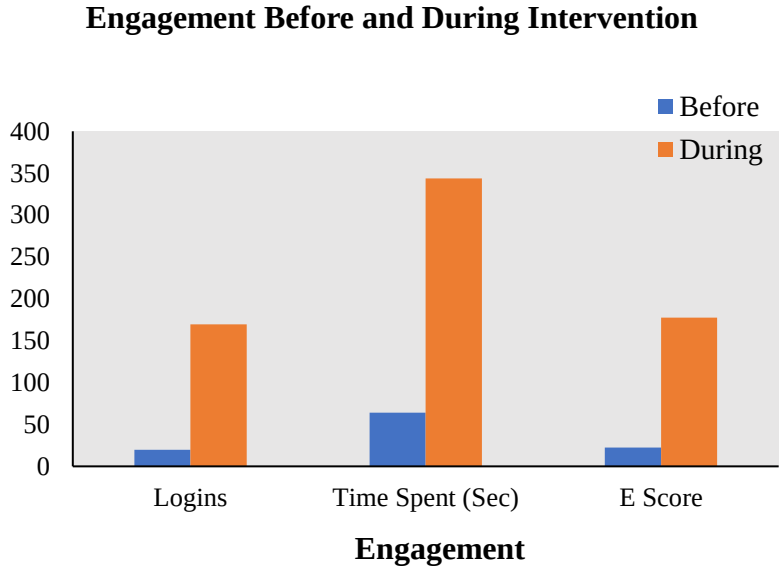

Figure 7.1. Engagement before and during the intervention on MindTap

Comparing Engagement on MindTap of Tailored and Non-Tailored Groups

Table 7.4 shows that there is a difference in engagement between tailored and non-tailored groups. To investigate the effect of intervention type (tailored and random/non-tailored) on students'

engagement in the MindTap system, RM-MANOVA was conducted. The RM-MANOVA test the effect of the persuasive system on students' learning activities, i.e. whether there was a statistically significant difference in engagement over time between the tailored and non-tailored group. The engagement was assessed using the weekly average of the number of logins, time spent on the MindTap system, and engagement score. The RM-MANOVA used time as a within-subject factor, intervention type (tailored versus non-tailored group) as a between-subject factor, and 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' learning engagement between the tailored and non-tailored group over time, $F_{3, 164} = 2.454$, $p = .066$, $\eta^2 = .048$. Univariate tests also indicate that there was no intervention type effect on the individual dependent variables: $F_{1, 164} = .094$, $p = .759$, $\eta^2 = .001$ for number of logins, $F_{1, 164} = .985$, $p = .323$, $\eta^2 = .007$ for time spent, and $F_{1, 164} = 3.453$, $p = .065$, $\eta^2 = .023$ for engagement score. Students who used the tailored version of the persuasive system were more engaged (as shown in Figure 7.2) than those who used the non-tailored version though the difference in engagement was not significant.

Table 7.4. Descriptive statistics of learning engagement before and during intervention use for Tailored and Non-Tailored

	Descriptive Statistics											
	Tailored						**Non-Tailored**					
	Number of Logins (Count)		Time Spent (Sec)		Engagement Score (Points)		Number of Logins (Count)		Time Spent (Sec)		Engagement Score (Points)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Engagement before intervention	20.058	1.205	7094.7	717.695	23.226	0.462	19.413	1.408	5887.176	614.272	21.834	0.539
Engagement during intervention	171.628	10.563	37886	4959.68	182.5	4.261	166.73	12.342	31771.4	4244.971	170.91	4.978

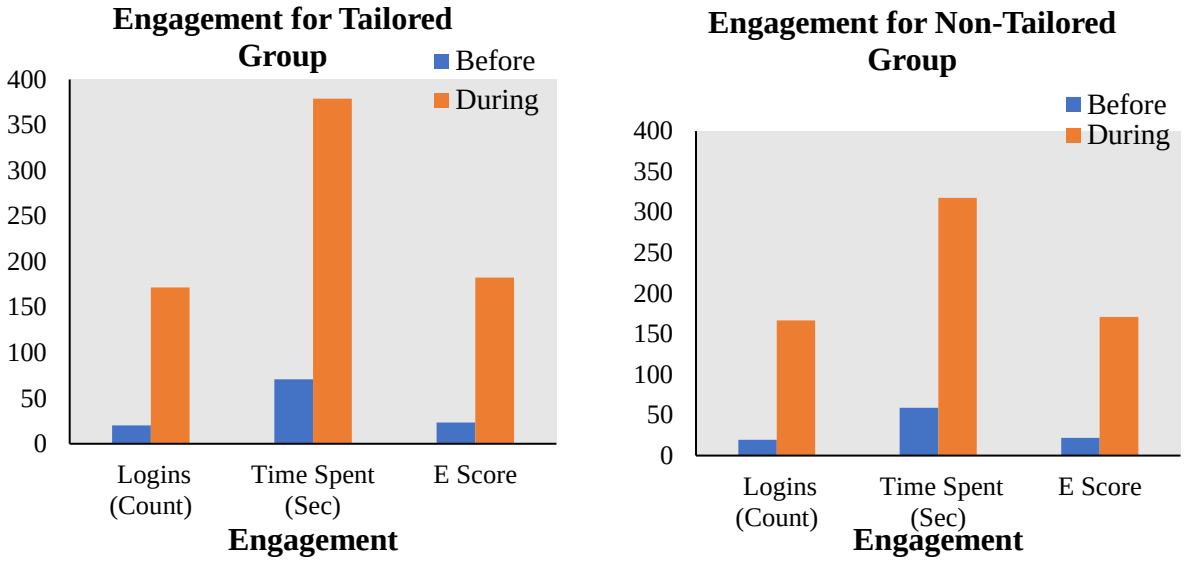

Figure 7.2. Engagement of Tailored and Non-Tailored groups in MindTap before and during the intervention

Comparing Students' Engagement on MindTap System Based on Social Influence Strategies (social comparison, social learning, and competition groups)

To examine the effect of the three different persuasive strategies on students' engagement, RM-MANOVA was conducted to test whether there was a significant change on students' engagement in their learning activities between the student groups in each experimental condition (social comparison, social learning, and competition). As before, the engagement was measured using the weekly average of the number of logins, time spent on the MindTap system, and engagement score. The RM-MANOVA used time as a within-subject factor, experimental condition as a between-subject factor, and the dependent variables were the number of logins, time spent on the system, and engagement score. The results of the RM-MANOVA reveal that there was no effect of students' groups on learning engagement for the all the three measures, $F_{2, 173} = .246$, $p = .783$, $\eta^2 = .003$ for number of logins, $F_{2, 173} = .778$, $p = .461$, $\eta^2 = .009$ for time spent, and $F_{2, 173} = 3.044$, $p = .050$, $\eta^2 = .034$ for engagement score. Though there was an increase in engagement during the intervention use, comparing the increase among the three students' groups (based on strategies) shows no statistically significant difference in engagement. This means that each of the three strategies is equally motivating to the group of students that used them.

Comparing Students' Engagement on MindTap System Based on Experimental Condition and Control Group

The intervention was in the second half of the class, after the midterm. To explore whether the students mobilize themselves to work harder (after the shock of seeing their midterm results) and confirm if the increase in engagement during the intervention was caused by the persuasive system, I investigated the effect of the persuasive visualization (visualization and no-visualization) on students' engagement in their learning activities. I performed RM-MANOVA to determine whether there exists a statistically significant difference in engagement between the visualization group and the control group (no-visualization) over time. The results reveal that there was a significant effect of visualization type on students' engagement ($F_{1, 206} = 371.947$, p =.0001, $\eta^2 = .644$) for number of logins, ($F_{1, 206} = 162.181$, p =.0001, $\eta^2 = .440$) for time spent on system, and ($F_{1, 206} = 3748.788$, p =.0001, $\eta^2 = .948$) for engagement score. The pairwise comparison results show that the visualization group was more engaged in the system than the control group (as shown in Figure 7.3), p< .05.

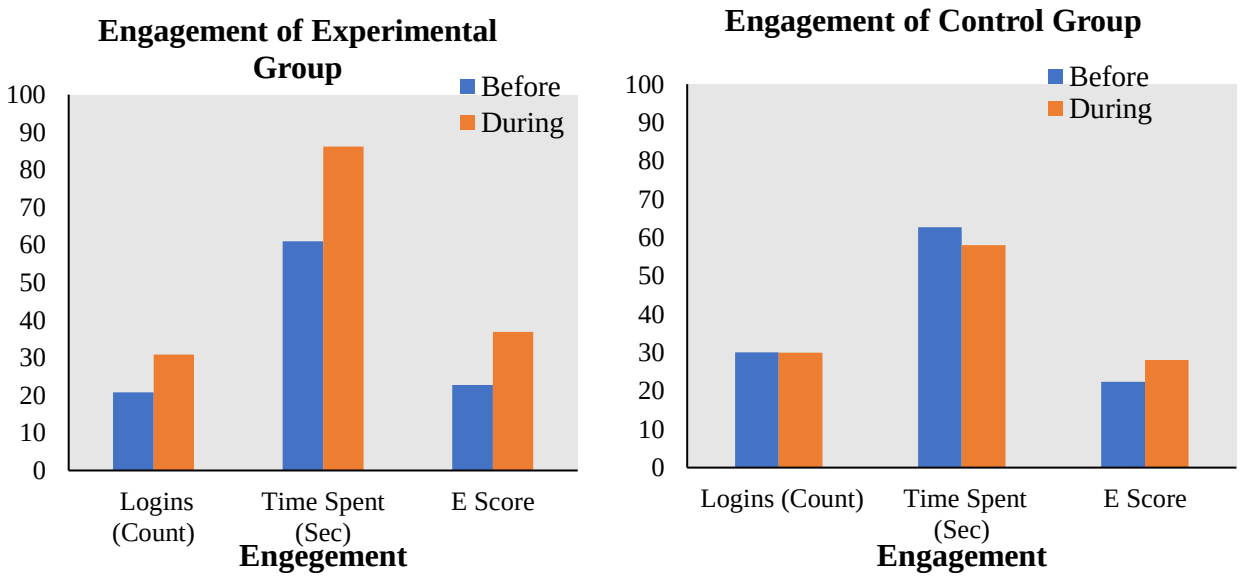

Figure 7.3. Engagement of Experimental and Control groups in MindTap before and during the intervention

To evaluate the engagement of the students with the persuasive system/SARA (in contrast to the actual learning system MindTap, which was already demonstrated in this section), I performed

similar analysis, but as a measure of engagement, I used the data log file of students' interactions with the persuasive system/SARA.

7.1.2 Determining the Persuasion Effect on the Students' Learning Engagement using Persuasive System Data Log File

Measurement of engagement/activity in computer applications involves analysis of logged users' activities in the system to determine their behavioural outcomes. Here, I define the features that are measured and how they are measured to obtain information on the students' engagement with the persuasive system/SARA.

- Frequency of the persuasive system usage measured by the number of hover/click events on the persuasive visualization.
- Frequency at which students read their personalized messages and view the visualization measured by the number of message view events in the event log.

7.1.2.1 Persuasive System Data Log File Analysis

Prior to the introduction of the persuasive system, students have been using the SARA system in their courses. The SARA system sends students personalized messages adapted to their learning in a particular course. The details of the SARA system and how the persuasive system was integrated to it were explained in chapters three and five, respectively. For the time before the intervention, the students didn't have access to the persuasive visualization, so the only measure that makes sense is the interaction of students with the SARA system. As a result, there are two ways that students' engagement were measured. First, engagement in this system was calculated based on the number of views event on SARA messages. The students used the system for seven weeks before the persuasive intervention was introduced. The persuasive intervention was then used for six weeks. To get the engagement score before the intervention, the weekly average of students message view for the seven weeks was calculated. For the engagement score during the intervention, the weekly average of students message view for the six weeks was computed. Another computation of engagement in this system involves the use of hover/click events on the persuasive visualization. The weekly average of hover/click events of students for the six weeks of intervention was calculated. Therefore in all time-based analysis for engagement, the message-view computation was used while hover/click on the visualization calculation was used for analysis

that compares engagement based on the different persuasive visualization versions or tailored versus non-tailored groups.

In determining whether there are significant differences in students' engagement in the SARA / persuasive system, I considered the following:

- Compared the overall students' activities on the persuasive system before introducing the intervention and during the intervention.
- Compared the overall engagement over time across students in the experimental condition (competition, social comparison, and social learning) using message view event log.
- Compared the overall engagement across students in the experimental condition (competition, social comparison, and social learning) using hover/click events on visualization.
- Compared the activities of students that used the tailored and those that used the non-tailored persuasive system with respect to the students' engagement with learning activities.
- Finally, compared the activities of the group of students that used the persuasive visualization (students that used the persuasive system) and the non-visualization group (students that didn't use the persuasive system).

In order to investigate the above-outlined conditions the following data analysis were carried out using the persuasive system data log file:

1) One-way within-subject ANOVA to compare students' engagement before introducing intervention and during the intervention.
2) Repeated measure ANOVA to compare engagement over time based on experimental condition using message view event log.
3) One-way ANOVA to compare the engagement of students based on the experimental condition they belong to (according to system versions) using hover/ click events on visualization.
4) Independent sample t-test to compare the number of hover/click events on the persuasive visualization by the tailored and non-tailored groups (Intervention Types).

5) Repeated-measure ANOVA to measure how often students belonging to each intervention type (tailored and non-tailored groups) view their messages before introducing the intervention and during the intervention use – change in engagement over time.
6) Repeated-measure ANOVA to compare the activities of students that used persuasive visualization (provided by the persuasive system) and those in the control group (students that did not use the persuasive system at all) over time.

7.1.2.2 Results of Engagement Based on Persuasive System Data Log File

In this section, I present results of analysis of persuasive/SARA log to determine the persuasive system effect on engagement in learning activities.

Change in Students' Engagement Over Time on the SARA Persuasive System as a Result of the Persuasive System Introduction

This analysis involves a comparison of overall students activities on the SARA system before and during the persuasive intervention. The descriptive statistics on students' engagement in the SARA system before the intervention introduction and during the intervention show difference in students activities within the system. The engagement scores (average weekly message view-event) of students 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 Figure 7.4. To evaluate the nature of the differences, I performed one-way within-subject ANOVA to examine whether a statistically significant difference exists on students' engagement before intervention introduction and during the intervention (engagement was assessed using the average number of message view events logged per week on SARA). The results show a statistically significant difference in the students' learning engagement ($F_{1, 191} = 198.080$, $p = .0001$, $\eta^2 = .596$). The pairwise comparison results demonstrate that students were more engaged in the persuasive system during the intervention compared to before the intervention in general, $p < .0001$. Engagement comparison between experimental condition and control group before and during intervention will help in confirming if the increase in engagement during the intervention was caused by the persuasive system.

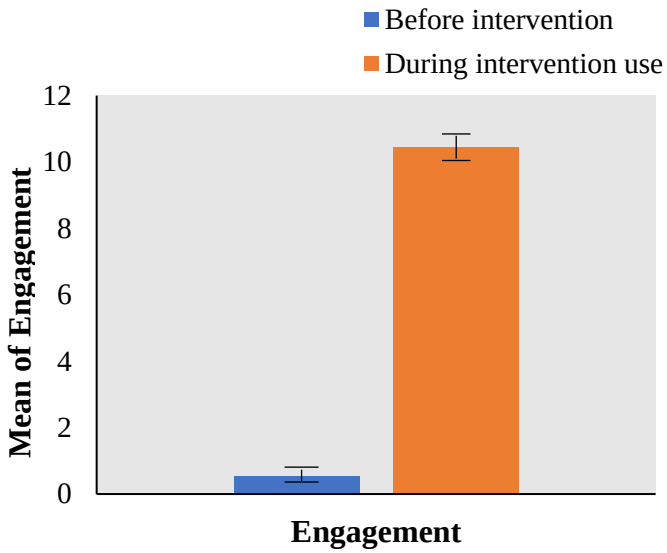

Figure 7.4. The mean level of engagement before and during intervention on SARA/Persuasive System

Change in Students' Engagement Over Time on the SARA Persuasive System based on Students' Experimental Condition

Students' activities over time in the SARA system were measured using their message view event log. To investigate whether a significant difference exists in the engagement of students' experimental condition, I performed a repeated measure ANOVA. The results show statistically significant difference between experimental condition over time on engagement ($F_{2, 191} = 5.283$, $p = .006$, $\eta^2 = .068$). This means that there was a statistically significant difference between the students' groups with respect to their engagement with the SARA persuasive system. To further evaluate the nature of the differences between the engagement across the three groups, I performed a post-hoc pairwise comparison. The pairwise results show that students who used the competition version of the persuasive system (competition group) were significantly more active (engaged) with the system than those that used social learning persuasive system version, $p < .05$. The difference in engagement between students that used the competition and social comparison persuasive system versions was not significant, $p > .05$. For social comparison and social learning, the results show that students that used social comparison version were more engaged than the social learning group, $p < .05$.

Comparing Engagement on the Persuasive System based on Students' Experimental Condition

This section compared the overall students' activities on the persuasive system based on students' experimental condition. Table 7.5 shows the descriptive statistics associated with students' engagement in the persuasive system based on the experimental condition they belong to (social comparison, social learning, and competition). The engagement here is measured using the average number of hover/click events on the persuasive visualization per week. The statistical analysis shows that students that used the competition version of the persuasive intervention had the highest mean level of engagement (M=16.28), followed by the social comparison (M=8.37), and the social learning (M=7.99) groups, as depicted in Figure 7.5. To compare whether these differences in engagement across the three versions are statistically significant, I conducted a one-way between-groups ANOVA.

Table 7.5. Descriptive statistics based on students' experimental condition (groups)

Descriptive Statistics		
Experimental Condition	**Mean of Engagement**	**Standard Deviation**
Social Comparison	8.37	7.43
Social Learning	7.99	9.37
Competition	16.28	17.54

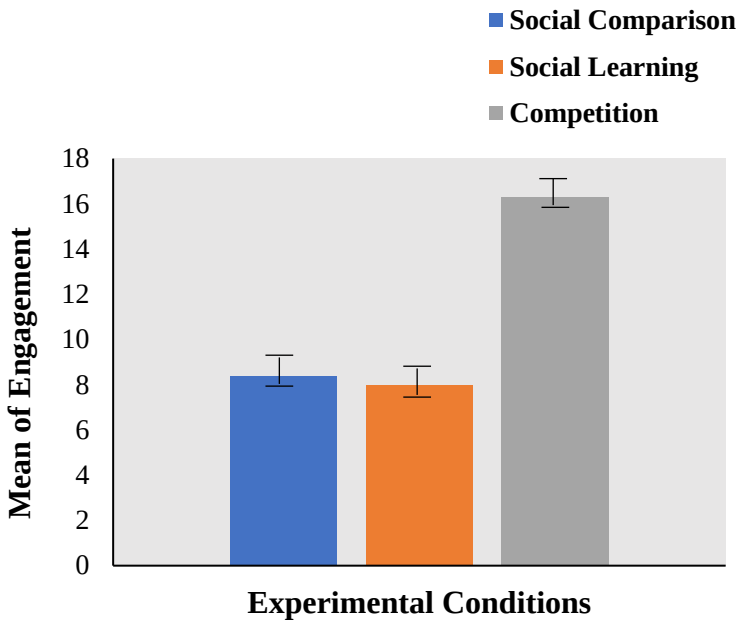

Figure 7.5. Mean level of engagement for the experimental condition on the Persuasive System

One-way ANOVA Result

The results of the one-way ANOVA comparing the activities of the three student groups (that used the three distinct versions of the persuasive system) show that there was a statistically significant main effect of experimental condition on students' engagement ($F_{2, 190} = 8.684$, $p = .0001$, $\eta^2 = .054$), engagement assessed using the average number of hover/click events on the persuasive visualization per week. This means that there was a statistically significant difference between the students' groups with respect to their engagement with distinct versions of the persuasive system. To further evaluate the nature of the differences between the engagement across the three groups, I performed a post-hoc pairwise comparison. The pairwise results indicate that students who used the competition version of the persuasive system (competition group) were significantly more active (engaged) with the system than those that used the social comparison and social learning persuasive system version, $p < .0001$. The difference in engagement between students that used the social comparison and social learning persuasive system versions was not significant, $p > .05$.

Comparing Tailored and Non-Tailored Persuasive Versions

In this context, the activities of students in the persuasive system were compared based on the intervention type (tailored or random). The descriptive statistics of students' engagement in the persuasive system between intervention type (the tailored and non-tailored groups) in Table 7.6 and Figure 7.6 shows that the tailored group had a numerically higher mean level of engagement (M=10.25, SD=9.80) than the non-tailored group (M=8.00, SD=9.25), engagement measured by the average number of hover/click events on the persuasive visualization per week. In order to examine the difference in engagement due to the effect of intervention type on students' learning activities, I conducted an independent sample t-test. The results of the t-test show a statistically significant difference of intervention type on students' engagement, $t_{180} = 2.04$, $p = .043$. Specifically, the tailored group that used their preferred persuasive system version designed with the strategies that they are susceptible to scored higher on engagement than those in the non-tailored group (randomly assigned group).

Table 7.6. Descriptive statistics of the intervention types

Descriptive Statistics		
Intervention Type	**Mean**	**Standard Deviation**
Tailored	10.25	9.80
Non-Tailored	8.00	9.25

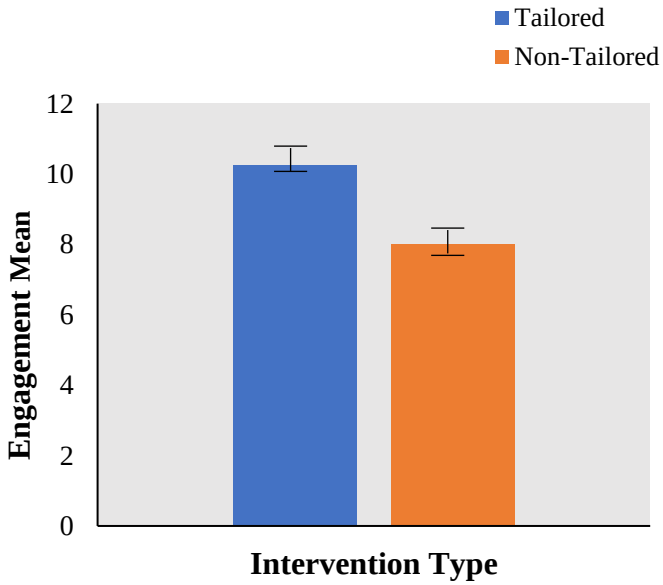

Figure 7.6. Mean level of engagement for the intervention type on the Persuasive System

Change in Students' Engagement Over Time in the SARA Persuasive System 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 as a result of using the intervention. To achieve this, I performed a repeated-measure ANOVA using time as a within-subject factor and intervention type as a between-subject factor on students' engagements, engagement assessed using the average number of SARA message view event logged per week. In general, the result shows that there is a significant main effect of the intervention type on students' engagement over time ($F_{1, 180} = 9.49$, $p = .003$, $\eta^2 = .066$). This means that a significant difference exists between the engagement of the tailored persuasive strategy and the non-tailored (random persuasive strategy) groups. The results of the pairwise comparison show that students who used the tailored version of the persuasive system were more engaged in the SARA persuasive system than those who used the non-tailored version (as depicted in Figure 7.7), $p < .05$. For the engagement of the students before introducing the intervention, the tailored group (M=0.51, SD =1.201) and the non-tailored group (M=0.58, SD=1.177) while during the intervention; the tailored group (M=12.50, SD=9.076) and the non-tailored group (M=8.26, SD=7.050).

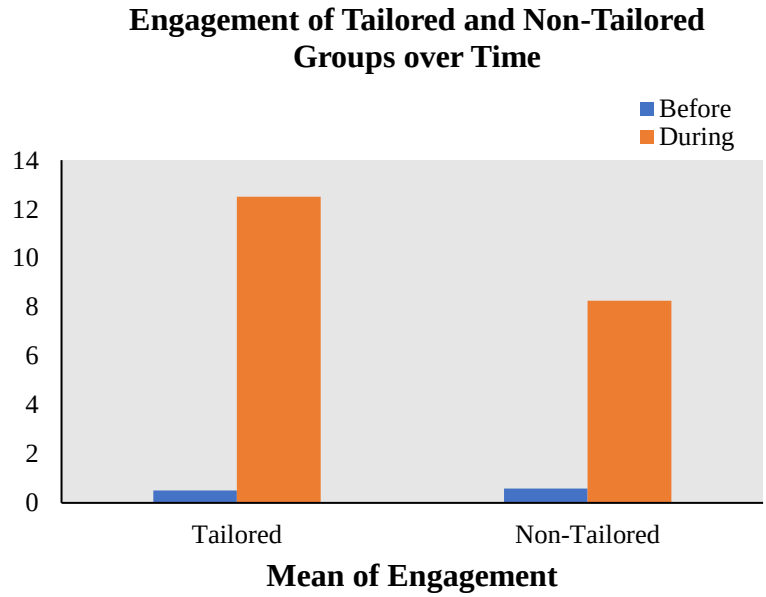

Figure 7.7. Engagement of Tailored and Non-Tailored Group before and during the intervention on SARA/Persuasive System

Overall, this means that introducing the persuasive system promoted students' engagement and that tailoring the persuasive strategy (visualization) to the user's preference amplifies the persuasive effect.

Comparing the Engagement of the Experimental Condition and the Control Group

It might be argued that an increase in students' learning engagement was as a result of their mobilization after seeing their midterm results. To examine this thought and verify if the increase in engagement during the intervention was as a result of the persuasive system, I compared the engagement of the experimental condition (students that used persuasive visualization) with the baseline (no-persuasive visualization). I performed a repeated-measure ANOVA using time as a within-subject factor and visualization type (visualization and no-visualization) as a between-subject factor. The engagement was measured using the average number of message view events logged per week. The results reveal that there was a significant main effect of visualization type on students' engagement ($F_{1, 226} = 20.55$, $p = .0001$, $\eta^2 = .056$). This means that there was a difference in students' learning engagement between the visualization and no-visualization group over time. The pairwise comparison results show that students who used the persuasive visualization (the persuasive system) were more engaged in the persuasive system than the control group (those that used no-visualization), $p < .05$. Figure 7.8 shows the engagement of visualization and no-visualization groups over time. Specifically, students that used the persuasive system were more attentive to information provided by the system, because they were more active with the persuasive system than the students that did not use the persuasive system.

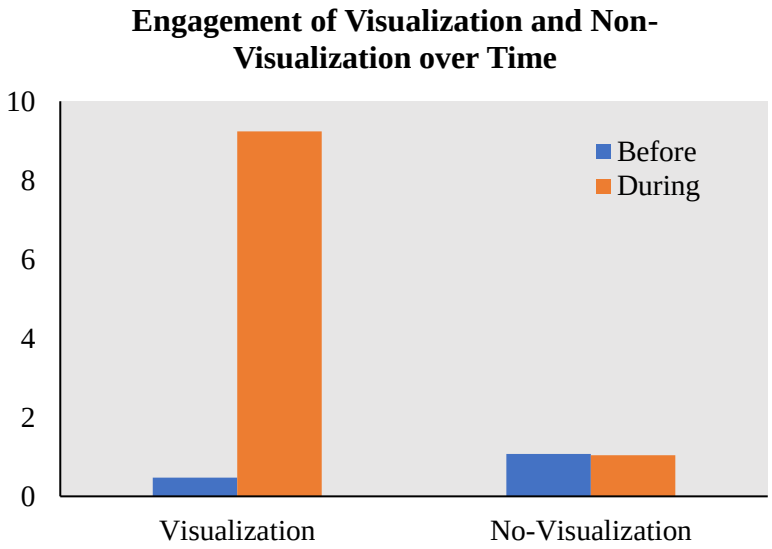

Figure 7.8. Engagement between visualization and no-visualization (control) groups before and during the intervention on SARA/Persuasive System

Having investigated the effect of the persuasive system on students' engagement in their learning activities using MindTap and persuasive system data log files, the next section examines how students perceived the persuasive system.

7.2 Evaluation for Perceived Persuasiveness of the Persuasive System

The persuasive system exit study was designed to investigate the effectiveness of the three persuasive system versions for motivating students' engagement in their learning activities. Specifically, it measures the perceived efficacy of persuasive system versions implementing the three social influence PT strategies (social comparison, social learning, and competition) at motivating students to engage deeply in their learning activities. This section describes in detail the system exit survey, data analysis, and the results.

7.2.1 Measurement Instrument

For the purpose of this analysis, tailored version involves 96 students, contra-tailored involved 11 students, no-visualization consists of 35 students, and non-tailored version consists of 86 students. Students who participated in the persuadability inventory (PI) survey before the experiment used a tailored system version while others were randomly assigned, details were presented in Table

7.1. To elicit feedback on the persuasiveness of the three system versions implementing the individual social influence strategies, I employed a validated tool for assessing perceived persuasiveness of systems. The tool was adapted from Orji et al. [76] and has been used in other PT research works [73, 74, 79]. The tool consists of fours questions:

1) "The system would influence me."

2) "The system would be convincing."

3) "The system would be personally relevant for me."

4) "The system would make me reconsider my study habits."

I employed the questions to design an online *system exit survey* which the students filled out at the end of the system usage. The questions were measured using participants' agreement with a 7-point Likert scale ranging from "1 = Strongly disagree" to "7 = Strongly agree".

7.2.2 Data Analysis for Evaluation of the Persuasive System

To measure the persuasiveness of the three versions of the persuasive system (the social comparison, the social learning, and the competition version) and evaluate the effectiveness of the tailored compared to the random assignment of students to versions, I employed some well-known analytical techniques and procedures. The following steps were followed to analyze the data.

1. Kaiser-Meyer-Olkin (KMO) sampling adequacies and the Bartlett Test of Sphericity were used to determine the suitability of the data for analysis.
2. After establishing the suitability of the data, I conducted a one-sample t-test on the data measuring the persuasiveness of each persuasive system version separately to establish their individual persuasiveness overall.
3. Next, to examine and compare the persuasiveness of the three persuasive system versions, I computed the average persuasiveness score for each strategy and performed a One-Way ANOVA after validating for ANOVA assumptions.
4. Finally, to compare the efficacy of the tailored and random assignment intervention types with respect to their ability to promote learning engagement among students, I conducted an independent sample t-test.

The detailed results of the analysis are as presented below.

7.2.3 Results of System Perceived Persuasiveness

In determining the suitability of the data using Kaiser-Meyer-Olkin (KMO) sampling adequacy and the Bartlett Test of Sphericity, the results show that the KMO was 0.764 and is above the recommended value of 0.6. The Bartlett Test of Sphericity was statistically significant ($\chi 2$ (6) = 548.12, $p < 0.0001$). These results show that the data were suitable for further analysis [57, 69].

The Persuasiveness of the Persuasive System Versions

Table 7.7 shows the detailed results of the one-sample t-test examining the persuasiveness of each system version: the overall mean score (M), standard deviation (SD), t-values (t), the degree of freedom (df), the mean difference (MD), and the significant levels (p) of the persuasiveness rating for the persuasive system versions on a scale from 1 (low) to 7 (high) using a confidence interval of 95%. The neutral score for the persuasiveness tool is 3.5.

Table 7.7. The results of one-sample t-test on the persuasiveness of the system versions

Strategies	M	SD	t	df	p	MD
Social Comparison	4.643	1.424	7.613	104	.0001	1.143
Social Learning	4.391	1.636	3.773	66	.001	0.891
Competition	4.279	1.348	2.382	20	.030	0.779

Each version of the persuasive system was used by different groups of students and each group rate the version that they used. From the one-sample t-test, I established that the three persuasive system versions: social comparison, social learning, and competition were rated as significantly persuasive with persuasiveness score higher than the neutral value (median rating) of 3.5 as shown in Table 7.7 and Figure 7.9, social comparison (M= 4.64, SD = 1.42, t_{104}= 7.61, p = .0001), social learning (M = 4.39, SD = 1.64, t_{66} = 3.77, p = .0001), and competition (M=4.28, SD = 1.35, t_{20} = 2.38, p = 0.03). Overall, the system implementations of the three strategies were perceived as persuasive by the students.

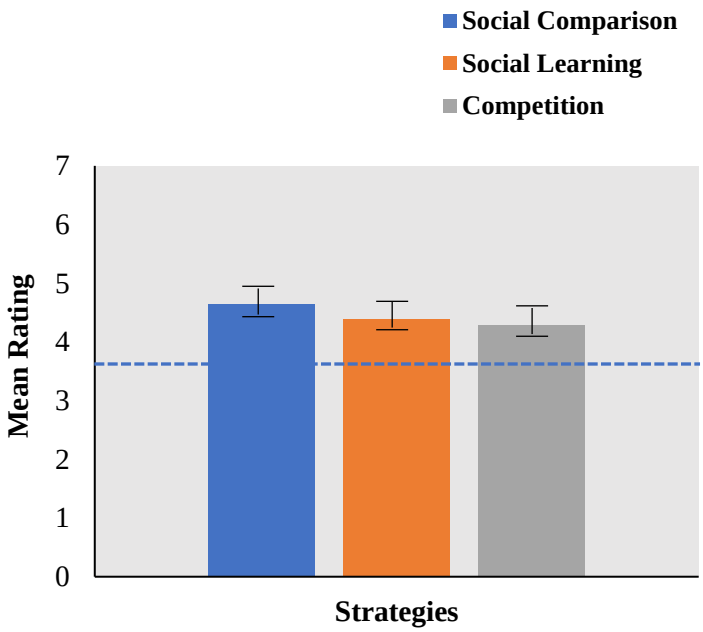

Figure 7.9. A bar graph of the mean of the individual strategies showing their overall persuasiveness

Comparison of the Persuasiveness of the Three Persuasive System Versions

The results of one-way ANOVA show that there was no statistically significant difference between the three persuasive system versions with respect to their persuasiveness ($F_{2, 190} = 0.711$, $p = .493$). This means that each of the system versions is equally motivating to different groups of students that used them. In general, social comparison version was perceived as the most persuasive followed by social learning, and lastly the competition, though the difference was not statistically significant.

Comparison of the Persuasiveness of the Tailored and Non-Tailored groups

Table 7.8 shows the descriptive statistics and independent sample t-test results between tailored and non-tailored students' groups. There was a statistically significant difference in the persuasiveness of the system between the tailored group and the random group, $t_{132.74} = 2.66$, $p = .009$. Specifically, the students in the tailored group that used their preferred persuasive system version rated the system as more persuasive than the students that were randomly assigned to use any of the system versions without considering their strategy preference.

Table 7.8. The results of the independent sample t-test between tailored and random groups

Group Statistics (Equal Variances not assumed**)**						
Groups	N	Mean	Std. Deviation	df	t	p
Tailored	96	4.83	1.20	132.74	2.66	.009
Random	86	4.20	1.68			

7.3 Summary of Analysis

The persuasive system evaluation tests the validity of the three social influence strategies employed in the system design in affecting learning behaviour positively using subjective measure (students' ratings). The evaluation established that the three strategies can be implemented in PT to encourage students in increasing their learning activities.

The objective measures of students' activities using the persuasive system and MindTap data log files confirm the efficiency of the three strategies at affecting students' learning behaviour positively. The results are summarized below:

1) The intervention motivated deeper students' engagement on their online systems (persuasive system and MindTap) overall, as shown by the measured students' learning activities.
2) Interestingly, it seems that there was no clear winner among the strategies. This means that none of the three versions of the persuasive system resulted in a significant difference in student learning activities than the others.
3) The students that used their preferred persuasive system version rated the system as more persuasive than those that were randomly assigned to the versions without regard to their persuasive strategy preference. Also, the tailored group performed more activities on the persuasive system than the non-tailored group. The activities of the tailored group on MindTap were more than that of the non-tailored group but the difference was not significant.
4) Students that participated in the persuasive intervention were more engaged in their learning systems (MindTap and SARA persuasive system) compared to those in the control group.

5) The results suggest that persuasive systems will be more effective at promoting students' engagement in their learning activities when they are directly visible in the learning system.

7.4 Users' Feedback

This section provides a summary and a brief discussion on users' (students) feedback sent through the persuasive system. The students paid precise attention to the strategies implemented in the persuasive system as shown by their feedback. They reflected on the information provided by the persuasive visualization. For example, among the students that performed very well in their assessments, the major response given was "*I am really satisfied with my grades*". However, some of the students were surprised by the information provided in the persuasive system visualization. Below are some of the comments from the students in response to the persuasive visualizations.

- *"better grade than expected"*
- *"Didn't expect to be doing this well!"*
- *"Happy that I did so well but think I could have got even higher"*
- *"honestly didn't expect to do this well"*
- *"I am over the class average"*
- *"I studied a lot and deserved a good mark, but the exam was ridiculous"*
- *"I studied hard. Thought it was going to be higher"*
- *"I thought I did better"*
- *"I'm at the top of the class!"*
- *"surprised I did so good on the midterm yet so bad on the lab exam*"

Based on the comments, some students were surprised because they performed better than they expected in their assessments while others were surprised by their inability to get their expected grades. The comment "*I thought I did better*" shows that those students compare themselves to the ones that performed excellently in the assessments.

Moreover, students that were not happy with their performance provided comments such as:

- "*because I didn't do well"*
- *"because I know I could do better but somehow my grades are not good at all"*
- *"because I studied for chem and bearly passed and now failed this one instead"*

- *"because my midterm mark is horrible"*
- *"Felt some of the material on the midterm the prof stressed wasn't going to be on it, and a lot of content covered or was heavily focused on in class wasn't on it."*
- *"I am not getting the grades I want to get.*
- *"how I got so low grades"*
- *"I did not get over 83"*
- *"I don't know how to study"*
- *"I failed this course last semester"*
- *"I should be doing better, its just a poor effort on my part"*
- *"I thought I was well prepared for the class midterm"*
- *"I usually do better, and I know I can, but I just don't have the time. I know a lot of this stuff already, so I often don't review as much as I should."*
- *"I usually do better but have been preoccupied with my full-time job"*
- *"I usually do better than this and I know I can do better. "*
- *"Wish my grade was higher"*
- *"not getting the grades I want to get"*

These comments from students were quite interesting. They show that the persuasive system gave the students the opportunity to reflect on their learning behaviour and what they are doing right or wrong. For instance, some comments such as "*I should be doing better, its just a poor effort on my part*", "*I don't know how to study*", "*I usually do better, and I know I can, but I just don't have the time. I know a lot of this stuff already, so I often don't review as much as I should.",* and "*I usually do better but have been preoccupied with my full-time job*" suggest that the students by reflecting on their learning outcome were able to identify some of the hindrances to achieving their desired academic performance/grade. This is in line with the knowledge-attitude-behaviour (KAB) model which states that awareness knowledge provides people with knowledge specific to their situation to motivate them. The persuasive system provided an opportunity for students to be frequently reminded of their learning goals and progress to promote learning.

It was motivating for the students to monitor their assessments grades because based on the information provided by the persuasive visualization students that performed poorly recognized that some of their peers performed excellently well in those assessments. As shown in comments

such as "*because I know I could do better but somehow my grades are not good at all*", "*I failed this course last semester*", "*because my midterm mark is horrible*", and "*surprised I did so good on the midterm yet so bad on the lab exam*". There are two rationales to the students' motivations. Students who got excellent grades will continue to be motivated to maintain their excellent grades while those with low grades will be persuaded to spend more time in their learning activities to achieve a better grade like their peers.

Hence, all the comments from students and the results of the system exit survey suggest that students appreciated the three PT strategies employed in the system design. Therefore, this reinforces the idea that socially-oriented PT strategies can be employed in educational technology design to influence students to change their learning behaviour and promote more active engagement. Also, it supports the hypothesis that students react positively to social influence-driven persuasive systems.

CHAPTER 8
CONCLUSION AND FUTURE WORK

In education domain, research has shown that persuasive technology can be applied in various ways to achieve specific goals. PT has been used in teaching complex topics[7, 12], motivating people to enter a higher education [95], educating people with learning disabilities [2, 67], and for self-regulated learning [38, 85]. The efficiency of these applications depends on the implementation of PT strategies employed in their design. Therefore, understanding the influence of persuasive principles and strategies on students'engagement in their learning activities will help in designing appropriate persuasive application for the education domain. The existing research works on PT in education had not investigated the effect of social influence strategies in accomplishing specific goals. However, research has established the effectiveness of applications built with socially-oriented PT strategies in achieving desired goals in e-commerce and health. Moreover, research established that personalizing PT applications make them more effective than a one-size-fits-all approach. Hence the success of PT applications depends on the use of an appropriate persuasive strategy for each user type.

This thesis investigated the effect of social influence strategies of PT in encouraging students for active engagement in learning to improve academic performance. To achieve this, I developed a prototype of a persuasive system with three social visualization versions. Each visualization operationalizes one influence strategy using students' assessment grades. In order, to test the motivational effect of the visualizations on encouraging students in active learning activities, I carried out research using the persuasive system. In determining the real effect of the persuasive system designed with the strategies on students, this thesis employed both quantitive and qualitative analysis of students' data. It examined the effectiveness of adapting PT applications for education using students' persuasion profile. The results of data analysis in this thesis effectively answered the broad research question; "*can socially-oriented PT strategies be used to motivate students to increase their engagement in learning and improve academic performance?".* The results established that the three strategies could effectively be used to motivate students to improve their engagement in learning activities which will consequently improve their academic performance. The results further show that tailoring persuasive strategies to students' preferences enhances the students' experience with a system designed using the strategies and increases the

effectiveness of the system to inspire the students to achieve a desired goal. The high rating of the persuasive system and high engagement with the persuasive system by the tailored group demonstrated this. Hence, designers can personalize PTs to an individual student using group-based (grouping students with the same persuasive strategy preference together) tailoring as demonstrated in this thesis.

The evaluation of the three versions of the persuasive system and the influence of each version at improving students' engagement in learning show that a single appropriate PT (determined using students' persuasion profile) strategy can be employed to promote a desired behaviour change among students. Each version demonstrated to be effective in encouraging the students that used it to engage more in their learning activities.

Moreover, the findings indicate that direct incorporation of a persuasive attempt on students' learning system made students more motivated to engage in their learning activities. Therefore, designers of PT for promoting students' learning should always integrate PT within students' learning environment.

8.1 Discussions

This section discusses the implications of the findings in the analysis of engagement and the evaluation of the persuasive system. It highlights some precise insights from the analysis to answer the research questions of this thesis and establish the feasibility of the social influence strategies at achieving a desired goal in education.

8.1.1 How do the Students Perceive the Three Versions of the Persuasive System?

The findings in this research show that socially-oriented PT (social comparison, social learning, and competition) can effectively be applied in university education to promote desirable learning behaviour among students. Though the three strategies differ in their operationalization in the system design, students acknowledged their effectiveness in promoting learning behaviour (engagement) overall. Based on the system evaluation results, all the students that used the system perceived as persuasive the implementation of the three strategies with respect to their ability to motivate students to engage in their learning activities. Thus the research question *How do the students perceive the three versions of the persuasive system?* has been answered by showing that

persuasive social visualizations designed based on social influence persuasive strategies (competition, social comparison, and social learning) are perceived by students as promoting learning and engagement.

8.1.2 Does Tailoring Persuasive Systems Increase the Perceived Persuasiveness of the System?

Moreover, the results reveal that tailoring the persuasive system to students using their persuasion profile amplified the perceived persuasiveness of the system. The higher rating of the system persuasiveness by students in the tailored condition established this. This answers the research question *Does tailoring persuasive systems increase students' perceived persuasiveness of the system?* This means that tailoring persuasive systems to match user's persuasion profile will increase their perceived persuasiveness with respect to their ability to promote students' engagement in learning activities.

8.1.3 Is there a Difference in the Perceived Persuasiveness of the Three Social Influence Strategies Overall?

The results demonstrate that there was no significant difference between the three social influence strategies with respect to their persuasiveness. This means that the perceived persuasiveness of the three strategies among different groups of students that use them would be assumed to be equal. This suggests that the social influence strategies are not fundamentally different in their effectiveness overall, as each of the three strategies equally motivated different groups of students.

8.1.4 Does the Persuasive System lead to Deeper Learning Engagement Overall?

The data log of interaction analysis of the Persuasive system (including the SARA agent and the persuasive visualization) and the MindTap system (where students practised) showed interesting results. The results of engagement comparison within the Persuasive system between those students who used the persuasive system with visualization and the control group who used the persuasive system without visualization (i.e. who used just SARA) show that those who used the persuasive system with visualization engaged in significantly more activities with SARA than the control group. Moreover, in the MindTap system, the students that used the persuasive intervention were more engaged in their learning activities than those in the control group.

8.1.5 Does any of the Strategies lead to More Students' Engagement than the Others?

The results from the persuasive system access log reveal that the competition strategy tailored group had a significantly higher number of activities than the social comparison and social learning strategy groups. This, however, may be a result of the method used to select students for the tailored competitive group – they had to be strong students with preference to competition. Such students are likely more active and engaged by nature. There was no significant difference in engagement between the social comparison group and social learning group.

From the results of the online MindTap log, no significant difference in students'engagement was found among the three students' groups.

Moreover, the results of the questionnaire for the perceived persuasiveness of the three visualization versions established that no significant difference existed between them. Although based on the mean scores of the persuasiveness of three versions, social comparison was rated highest by students, subjective ratings may not reflect students' actual behaviour. Overall, each of the three strategies equally motivated the student's groups that used them. This refutes the hypothesis *Other factors being equal, the social comparison strategy will motivate students to engage more in learning than the social learning strategy or the competition strategy.*

8.1.6 Is there a Difference in Engagement Between the Tailored and Non-Tailored Intervention Condition?

The results of the persuasive system log show that students that used the tailored intervention performed more activities on the persuasive system than those that used the non-tailored intervention. However, the results of MindTap log demonstrate that the difference in the engagement of tailored and non-tailored group is not significant. The possible reason for the non-significant difference in engagement based on MindTap data between the two groups may be because some student may prefer to use textbooks and engage in learning activities offline or use other materials available on the web – outside MindTap.

8.1.7 Relationship Between System Perceived Persuasiveness and Engagement in Learning Activities

Despite that students used different versions of the persuasive system based on their experimental condition. The results indicate that the perceived persuasiveness of the three system versions did not differ significantly among the experimental condition (social comparison, social learning, and competition) of students. Moreover, results of students' engagement in their actual learning system also show no significant variation in engagement of students based on the experimental condition. It means that the strategies can ultimately improve changes in actual behaviour (learning activities). The results of the comparison of engagement between the experimental condition with the control group of students confirmed this. The indication is that the strategies can independently be employed to achieve a desired goal in educational software.

8.1.8 Determining Students' Strategy Preference Objectively

The persuasive system in this research implemented strategies as versions and the students in this study were assigned to different persuasive system versions using their persuasion profile and random assignment. This thesis has opened another way that students' preference to PT strategy can be objectively determined. A persuasive system could be developed, and different PT strategies implemented as versions in the system. The students' access to the different versions will be logged and their activity log would provide information about the version each student spent more time on. The analysis of the activity log can be used to develop a model that will facilitate in adapting the versions of the persuasive system to the students.

8.1.9 The Design Context for the Persuasive System

In the Persuasive System Design (PSD) framework, social comparison and competition are listed as separate strategies and they have been used in many PT intervention designs. The two strategies are related in their implementation. According to the framework, in social comparison – the system should provide means for users to compare the results of their performance of a task with the performance of other users. For competition – the system should provide a means for competing with others. Based on this, the competition strategy emphasizes the user's rank among the competitors as shown in the competition persuasive visualization while in social comparison there

is no ranking, but the visualization presents information that will allow the user to compare her progress in a task/behaviour to that of other users. The social learning persuasive visualization provides the user learning outcome of other students. The user learns through observation, imitation, or modelling of other users' outcome. In most PT designs, these strategies are achieved as a design goal or based on system usage. For example, Stibe et al. [91] implemented the three strategies in their visualization. To facilitate social comparison, they display the number of tweets each user submitted. The number of tweets for each user changes colour as it increases to make comparison easy. For the competition, they ranked users based on their number of tweets. To allow for social learning, they displayed newsfeed from users so that others can observe and learn.

8.2 Contributions

Socially-oriented PTs have been shown to be effective at helping people to achieve desired goals in various domains. To the best of my knowledge, their effect at motivating university students to improve engagement in their learning activities has not been explored. This thesis presents the details of research works carried out to answer the research question: "*can socially-oriented PT strategies be employed to motivate university students to increase their engagement in learning and improve academic performance?*". The research in this thesis may contribute to persuasive technology and education literature in various ways.

Firstly, the studies in this thesis were performed in an actual university course environment with real students, therefore the results reflect real-life implications of the three social influence strategies on students' engagement and learning. The research presented in this thesis provides a real-world evaluation of the three persuasive strategies employed in this research through the use of subjective and objective measures in determining the effectiveness of the three strategies. Secondly, this thesis provided a proof of concept that the three social influence strategies of PT can be implemented in PT design for education to encourage students for improved learning engagement. It achieved this by developing three versions of a socially-oriented persuasive system for education based on social visualization and designed using three persuasive strategies: social comparison, social learning, and competition. The visualizations create a community feeling for students; this enables them to monitor and compare their learning progress with that of their peers (those performing better than them) to encourage them to improve. This provides insights for

researchers and PT designers that the three PT strategies can be implemented in persuasive software for education to facilitate students' positive change of attitude and behaviour towards their learning.

Next, this thesis personalizes the persuasive system to students using their persuasion profile. To build a persuasion profile for each student, I conducted a study using persuadability inventory tool. In determining the efficacy of personalizing persuasive systems in education, this thesis investigated the effect of tailoring the persuasive system to students using their persuasion profile. It compares the engagement of students that used the tailored persuasive system versions to those that were randomly assigned to the system versions. The results of both quantitative (system exit survey) and qualitative (system log) analysis revealed that students that received the tailored version were more engaged than the non-tailored group. It means that in designing PT for education, using appropriate influence strategy for each student will make the persuasive system more efficient in achieving its goal.

Furthermore, the research works demonstrate that the three social influence strategies of PT employed in this research are effective at motivating desired behaviour and attitude change in terms of learning engagement in a university course. The students perceived the three persuasive system versions built with the strategies positively. Thereby responding to the research question, "*can socially-oriented PT strategies be employed to motivate university students to increase their engagement in learning and improve academic performance?*"

Finally, as far as I know, this is the first work to explore the effect of the three strategies on students' engagement in a real university course-based environment. The research involved theory guided design, software implementation, and evaluation in a real setting. I designed a persuasive system, implemented the system in a real university learning situation, and evaluated the effect of the persuasive system versions on students' engagement in learning activities.

8.3 Limitations

In this section, I present some limitations of the research works presented in this thesis. Despite the contributions of this thesis, there are potential limitations to the research studies presented. First, the research is limited to the context of one university course to promote students' engagement in their learning activities. The persuasive system was applied to only one course that the students were taking in that semester. Second, the thesis investigated the effectiveness of social

influence strategies of PT using only three out of seven social influence strategies by Oinas-Kukkonen et al. [71] since it wasn't possible to find how to meaningfully apply the remaining four strategies in the context of this class. Third, the findings in this thesis may not explain the long-term influence of the intervention on students' engagement as they used the intervention for only six weeks. It cannot be established if students' perception of the persuasive strategies will change if they use the system for a longer period of time. Next, students engagement measure was only based on their online activities; their learning with their textbooks and structured study sessions were not measured. Nevertheless, this thesis has demonstrated the effectiveness of the three persuasive principles of PSD 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. Though, the efficiency of the three strategies for encouraging users to accomplish a specific goal has been established in health and e-commerce.

8.4 Future Works

The research works in this thesis provided an understanding of the effect of the three PT strategies at encouraging students' engagement in their learning activities. The research had revealed that persuasive principles could be applied in an educational institution to enhance students' learning by evaluating the effectiveness of the developed persuasive system on students' engagement in their learning. Future research would be conducted to extend the research works as follows.

1. To examine the relationship between students' engagement in their learning activities and their academic performance. The results of the analysis in this thesis show that the three strategies led to improved students' engagement in their learning activities. Therefore, future work will investigate the relationship between improved students' engagement and their academic performance to establish any effect of mediation.

2. To explore the elaborated effects of the three persuasive principles on students' learning behaviour, investigation on the influence of the strategies on more than one course will be conducted. This could be accomplished by extending the persuasive system design to include some other courses that the students are taking at the same time. This will determine if the change in engagement and academic performance would persist across the courses.

3. The results in this thesis show that tailoring the persuasive system to students' susceptibility using the strategies employed in the system design is effective. Hence, future research could investigate other ways of tailoring the persuasive system to students apart from using persuasion profile. Research could explore personalizing persuasive systems to students using their personality, cognitive ability, and motivational influence level. Also, research could consider and validate the influence of other PT strategies for improving students' learning.

Moreover, research could consider the effect of the persuasive system on students'engagement in their learning activities based on gender, age, and culture. It would be interesting to evaluate the effect of the persuasive system on students' engagement and academic performance based on the students' gender and age to find if there is any mediating effect.

There are wide ranges of future research works on the use of PT for promoting students' learning uncovered by the findings from this thesis.

PEER-REVIEWED PUBLICATION WITH CONTENTS FROM THIS THESIS

Orji FA, Vassileva J, Greer J. Personalized Persuasion for Promoting Students' Engagement and Learning. International Workshop on Personalized Persuasive Technology, with the Persuasive'2018 Conference, Waterloo, April 2018.

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APPENDIX A

CONSENT FORM

UNIVERSITY OF SASKATCHEWAN

DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF SASKATCHEWAN
INFORMED CONSENT FORM

You are invited to participate in this survey aimed at identifying effective ways of designing persuasive technology interventions to promote learning among university students. Please read this form carefully, and feel free to ask the researchers any questions you might have.

Title of Study: Investigation of how Students respond to various Persuasive Strategies to inform the design of Persuasive Technology to promote Education and learning among university students

Ethics Application Number: BEH*# 17-431*

Researchers:
Julita Vassileva, Department of Computer Science (360-966-4886), jiv@cs.usask.ca
Jim Greer, Department of Computer Science, jim.greer@usask.ca
Fidelia Orji, Department of Computer Science (306-914-0180), fao583@mail.usask.ca

Purpose and Procedure: The goal of this research is to investigate the level of susceptibility of university students to different persuasive strategies. The study may contribute to the general research area of Persuasive technology (PT) design in Education and Learning. To achieve this, we have designed a set of questions that we need you to respond to. This can be achieved by answering the 10-15 minutes questionnaire by clicking on the survey link below.

https://fluidsurveys.usask.ca/surveys/13-aadzzwnyzxqxfss1xdpoz7jdnia/persuasive-in-education/

Potential Risks: There are no known risks in this study.

Potential Benefits: Findings from the study may provide more insight into how various persuasive strategies affect students' performance. This will help in tailoring PT applications to help individual student perform better academically.

Compensation: In appreciation for your time, you would be offered a chance to win a gift card of $50.00 CAD. Your NSID will be used to enter the draw and to link your demographics to your survey responses.

Confidentiality: This survey is hosted by fluidsurveys.usask.ca. The privacy of the information you provide is subject to the laws of University of Saskatchewan and Canada. By participating in this survey, you acknowledge and agree that your [answers/information] will be stored and accessed in the University of Saskatchewan secured storage with the same level of privacy protection provided by the University.

Dissemination of Results: Aggregated results from this study will appear in an MSc course report, thesis and articles published in peer-reviewed conferences and scientific journals.

Right to Withdraw: Participation in this survey is voluntary, and you can decide not to participate at any time or choose not to answer any questions you don't feel comfortable with. Survey responses will only be saved to the database once the student submitted.

Questions: if you have any question regarding the study, please feel free to ask the researchers at any point, including at a later time. This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. You could call (306) 966-2975 or email Research Ethics Office at ethics.office@usask.ca regarding any questions on your rights as a participant.

Follow-Up or Debriefing: If you would like to know the results of this study, you can contact the researchers.

Consent to Participate: By completing and submitting this questionnaire, your free and informed consent is implied and indicates that you understand the above conditions of participation in this study.

APPENDIX B

CONSENT FORM

UNIVERSITY OF SASKATCHEWAN

DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF SASKATCHEWAN
INFORMED CONSENT FORM

Information being requested:
You are invited to participate in this survey aimed at identifying your perception of class, lab, and support for students' success. In particular, how the SARA agent supported your learning.

Goals:
To determine the effects of personalized advice and persuasive social visualization on students' engagement and learning outcomes.

Research Studies being conducted:
BEH 16-177
BEH 17-431

Researchers:
Paul Dick, Department of Biology
Ken Wilson, Department of Biology
Amin Mausaui, Education Faculty
Vicki Squises, Education Faculty
Julita Vassileva, Department of Computer Science
Jim Greer, Department of Computer Science
Fidelia Orji, Department of Computer Science

Potential Risks: There are no known risks in this study.

Confidentiality: This survey is hosted by surveymonkey.usask.ca. The privacy of the information you provide is subject to the laws of University of Saskatchewan and Canada. No personally identifying data will be used, only aggregate form of data will be used.

Dissemination of Results: Aggregated results from this study will appear in an MSc course report, thesis and articles published in peer-reviewed conferences and scientific journals.

Questions: if you have any question regarding the study, please feel free to ask the researchers at any point, including at a later time. This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board.

Comments:
The Department of Biology would like to see your responses regardless of whether or not you choose to participate in the studies. On the last page of the survey, you will be given a choice about participation in the research studies.

APPENDIX C

STUDY INSTRUMENTS

1. Please, enter your NSID.

1. What is your Gender?

- ○ Male
- ○ Female
- ○ Other

2. What is your age?

- ○ 16 - 24
- ○ 25 - 34
- ○ 35 - 44
- ○ 45 - 54
- ○ 55+

On a Scale of 1 to 9, to what extent do you agree with the following statements? 1 Strongly Disagree, 9 Strongly Agree.

3. I push myself hard when I am in competition with other students in a course.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

4. I would like to participate in competitions where I'd need to challenge other students in my class.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

5. Generally, I tend to be more ambitious than other students around me in my class.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

6. I like to do better than other students in my class.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

7. I like competitive events (for example quiz competition).

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

8. In courses, it is important to me to be equal in academic performance to my peers.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

9. I like comparing my academic performance against other students' performance in a course.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

10. I would like to know what other successful students in a course have done, so I can feel more confident.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

11. It is important to me to know what other students in a course are studying.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

12It is important to me what other students think of me.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

13. I adapt my study style to that of my friends.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

14. I often modify my study patterns to fit with others.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

15. Before making academic decisions, I ask for advice from my peers or others who know better.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

16. I adopt my studying quick to the model of other students.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

17. I adapt my learning to fit with other students around me.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○

18. I take other successful students in a course as role models for my studying behaviours.

Strongly Disagree	2	3	4	5	6	7	8	Strongly Agree
○	○	○	○	○	○	○	○	○