SOCIAL GAMIFICATION IN MULTIMEDIA INSTRUCTION: ASSESSING THE EFFECTS OF ANIMATION, REWARD STRATEGIES, AND SOCIAL INTERACTIONS ON LEARNERS MOTIVATION AND ACADEMIC PERFORMANCE IN ONLINE SETTINGS

By

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Abstract

Gamification is the strategy of using game elements and game-design mechanics in nongaming contexts. Many companies have gamified their online applications to increase customers' motivation and engagement. Increased motivation is also a critical factor that influences learning performance in online settings; however, the question of how to retain newly gained motivation and transfer it into learning efforts is still a challenge in educational technology. This study investigated the ways that social interactions can be used to facilitate students' self-regulated learning in online education. The fundamental hypothesis underlying this research is that an integrative model of social gamification and multimedia instruction will promote students' self-discipline during the online learning process, which in turn assures a better learning performance within online education. This study has designed and developed a socially gamified animation to examine whether social gamification can increase the motivation and engagement of students and to facilitate students' learning of polar science knowledge in an online learning environment.

This study employed a between-subject design as an experimental design method to investigate the effect of the proposed socially gamified animation. In general, findings indicated that social gamification could improve students' content knowledge. In addition, students' increased cognitive engagement during the learning process has a positive impact on their learning performance. Discriminant analyses, however, did not support significant differences in cognitive engagement between students who learned with socially gamified animations and those students who did not. It is unclear whether the implementation of social gamification could promote higher level of motivation and cognitive engagement and whether this motivation and cognitive engagement subsequently results in advanced learning performance in online settings.

These findings have implications for understanding the motivational and instructional effect of social gamification in online learning. In addition, the design and development of the socially gamified animation investigated in this study provides an example of bridging the theory-practice gap in gamification of online education.

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Chapter 1: Introduction

Context of Study

The development of information technology (IT) with the capability of processing, displaying, and sharing information instantly has affected today's learning and teaching (Dillon & Gabbard, 1998; Pituch & Lee, 2006; Schwan & Riempp, 2004; Webster & Hackley, 1997). Technology-mediated distance learning, for example, facilitates information sharing and helps educational organizations overcome the limitations of time and space in knowledge dissemination (Allen & Seaman, 2011; Curran & Fleet, 2005; Pituch & Lee, 2006; Sun, Tsai, Finger, Chen, & Yeh, 2008; Webster & Hackley, 1997). If educational organizations cannot provide frequent services and trainings, online course materials and activities can accomplish the goals of compensating for insufficient on-site training opportunities and ensuring the quality of these services. In addition, this technology trend contributes to new types of mediated-learning experiences to enhance students' learning performance. These new types of mediated-learning experiences include using animation with interactive features that allow learners to interactively process the presented information and to attain more lucid understandings of the content (Schwan & Riempp, 2004).

Given the ubiquitous possibility for sharing of content and delivering knowledge in an engaging way, more educational organizations exhibit an increased willingness to implement eLearning to improve their programs (Allen & Seaman, 2011; Sun et al., 2008). For example, because of limited time and resources, the Center for Remote Sensing of Ice Sheet (CReSIS) at the University of Kansas (KU) cannot offer widespread support to enable all participants from various backgrounds to participate in its outreach programs. In order to allow those unable to access the programs to work with the learning materials without geographical and time constraints, CReSIS has developed and published various technology-mediated applications on its website, with no cost to the user, to widely disseminate the learning content to the public.

The interactive animation called *Glaciers in Motion* is one of the digital applications that CReSIS developed to provide more students with opportunities to access high-quality scientific learning materials. This interactive animation was designed to teach students basic knowledge of glaciers, including knowledge of how glaciers are formed, as well as how glaciers move, flow, and are distributed throughout polar climate zones. The development of its interface, graphics, and interactions were based upon Mayer's cognitive theory of multimedia learning (Mayer, 2005a) to reduce learners' mental efforts resulting from interacting with learning contents in the animation. Learners can use these freed cognitive resources in the process of recognizing the learning content in the animation to constructing new knowledge (Betrancourt, 2005; Clark & Mayer, 2011; Mayer, 2005a; Mayer & Moreno, 2003; Moreno & Mayer, 1999).

Since its design is based on the relevant multimedia learning principles validated in previous research studies, the implementation of such an animation was expected to improve students' content knowledge by engaging them in the learning process. The education team at CReSIS, however, conducted a between-subject design at West Middle School in Lawrence, Kansas, to evaluate middle school students' learning performances under three different instructional methods—the use of the animation, lecture-guided instruction, and a mixed instructional approach comprising animation and teachers' instruction. The initial results indicated that the use of animation alone, in comparison to lecture and the use of both lecture and animation, has less impact on developing students' content knowledge related to glacier science.

The preliminary findings from the assessment suggested that the current settings of the animation did not meet the original goals of engaging students and then improving their content knowledge of basic polar science. According to the researcher's observations, one possible, and perhaps the most likely, reason for this discrepancy relates to motivational orientation. Students who engaged with these web-based computer animations without access to teacher-led instruction easily lost interest in learning concepts over time. Less-motivated students would not be able to sustain their attention toward learning content for a long period of time, which may have resulted in poor academic performances. The results reflected a primary concern of successful eLearning: Students need more discipline to succeed (Allen & Seaman, 2013). Accordingly, it is essential to redesign the animation that can assist students with staying on task and with actively participating in the learning tasks. This study, based on Self-Determination Theory (SDT) (Ryan, & Deci, 2000) and the concepts of social gamification, proposed implementing game elements such as reward mechanism and social interactions into CReSIS animation. This study held the position that implementing these game elements within the eLearning application would support students' motivation and engagement to enhance self-discipline, which is essential for students to succeed in online education. The competition and collaboration involved in this game-based learning experience can motivate students to use various cognitive strategies to win rewards individually or collaboratively. Thus, the spirit of competition as well as a spirit of collaboration creates an engaging learning environment in which students actively participate in learning activities to learn the content and construct new knowledge.

Another objective of this research is exploring the means in which integrating social interaction in gamification can improve the effect of multimedia tools for online education. Group interaction is stressed as another important factor, resulting in a successful online learning environment (McInnerney & Roberts, 2004). The structured and systematic interaction in eLearning will enhance group awareness, which assists students interacting with learning materials and class activates in a critical and reflective manner for constructing knowledge (Garrison & Cleveland-Innes, 2005). In order to achieve desired research goals as well as to validate and employ sociocultural factors in online learning environments, this project integrated the theories that focused on computer-supported collaborative learning, including Activity Theory (AT), and other context-driven models. Therefore, the development of the gamified animation-integrated social functions, such as the online chat room, to verify the effect of students' social contexts in the processes of knowledge construction in online settings. In addition, peer and human-computer interactions were examined and to see whether, and/or to what extent, sociocultural effects also have an impact on students' motivations and cognitive engagement, which result in improved learning achievements. The outcome of this research can contribute to subsequent research on instructional effectiveness of social gamification in distance education and provide frameworks capable of addressing dynamic features of students' interactions in the online learning environment.

Issues of CReSIS's online animation. This research preliminarily investigated which obstacles deter the effectiveness of the CReSIS animation. This online animation was designed to support CReSIS outreach programs in teaching basic knowledge of glaciers for students in kindergarten through the eighth grade. Its design and development was based on Mayer's multimedia learning principles to reduce the cognitive load while the students engaged with the animation to construct new knowledge. Freed cognitive resources were expected to be exhausted within learning attempts, which increase germane cognitive processes, a series of mental efforts in the learning process (Mayer & Moreno, 2003). Although the animation, integrating a user-friendly interface, could provide an efficient way for users to receive the learning context

(Oviatt, Coulston, & Lunsford, 2004), the improved usability did not guarantee an increase in users' learning efforts to achieve a high level of critical thinking and knowledge construction.

One way to sustain students' attentions on the learning process is to apply instructional strategies to guide learners' attention toward critical features of the context and to assist them in controlling their learning paces (de Jong & van Joolingen, 1998; Renkl, 2005; Roy & Chi, 2005). Nevertheless, these strategies to be implemented in online learning environments still require learners to exert a substantial amount of self-discipline to focus on learning contents. Namely, using online animation similar to other online learning tools strongly relies upon an individual's determination and self-regulation to develop the critical and reflective thinking to fully understand the concepts of each lesson (Allen & Seaman, 2007; Kerka, 1996). Any external influence and interference may negatively affect self-discipline.

Self-determination and motivation. The current animation failed to adequately assist students in deeply engaging in the learning activities, which originally aimed for the result of authentic learning through personally meaningful practice within these subject areas to construct knowledge (Montessori, 1964; Piaget, 2013). Students' motivation toward the learning subject is the prerequisite psychological condition to achieve this deep learning (Gee, 2003). Motivation grounded in cognitivism comes in two broad categories: *intrinsic* and *extrinsic* motivation (Ryan & Deci, 2000a). Intrinsic motivation, unlike extrinsic motivation driven by external influences, exists within the individual and motivates a person's behavior by the interest and enjoyment inherent to the task itself (Ryan & Deci, 2000a). The current CReSIS animation seems to trigger only learners' extrinsic motivation by visually presenting complex learning subjects in an engaging format. For example, the implementation of vividly dynamic graphics to represent the way that glaciers move in the animation attempts to motivate learners to sustain their attentions toward the learning content (Alessi & Trollip, 2001). The initial evaluation, however, suggested that this method did not assist students in internalizing their interests, so students failed to exhibit intrinsic motivation toward learning content, nor did students demonstrate improved learning performances within the evaluation tests.

In addition, SDT indicates that the lower level of intrinsic motivation for learning a subject is insufficient and will quickly disappear (Deci, Vallerand, Pelletier, & Ryan, 1991; Ryan & Deci, 2000b). This type of intrinsic motivation fulfills only basic academic needs for remembering and understanding the learning content but does not tie to more immediate and concrete objectives for students to review and apply the newly gained knowledge to meet individual needs (Bloom, 1969). Therefore, it cannot assist students in remaining in the same active learning condition for a long period of time. In that situation, learners can still easily lose interest and subsequently lose attention concerning learning tasks in the animation. This high level of intrinsic motivation addressed in SDT should fulfill three inherent psychological needs: the need for developing competence, the need for relatedness, and the need for autonomy (Ryan & Deci, 2000b). Therefore, the animation needs to be improved to meet the aforementioned psychological needs, and then this instructional tool will be able to promote such an autonomous motivation toward achievement within students' learning processes.

According to SDT, the implementation of external regulations such as certain reward structures could increase students' content awareness to facilitate their internalization of the learning value gained from learning interests associated with engagement in animation-related tasks (Ryan & Deci, 2000b). Moreover, this external reward system should also meet the three core psychological needs to promote intrinsic motivation: supporting the knowledge and the competence expected to be learned in the animation, encompassing students' social context to generate relatedness with others, and also allowing students to initiate and regulate their own learning behavior to promote autonomous learning. Thus, this research proposed using reward structures with social networking functions in the animation as external regulations to provide learners optimal gaming experiences, which yield engaging experiences (Lazzaro, 2009). This research holds the position that these engaging experiences derived from these reward structures will in turn assist learners in sustaining intrinsic interest in the learning activities. With the implementation of sociocultural factors and gaming experiences to win rewards in this animation, the autonomous forms of motivation within students will be strengthened through accommodating three inherent psychological needs in the learning process: competence, relatedness, and autonomy (Deci et al., 1991).

Games as a learning medium. A great deal of research has shown the potential of gaming as an instructional method to improve students' learning performance through means of problem-solving, active participation, and situated learning (J. Dewey, 1938; Gee, 2005; Piaget, 1962; Prensky, 2007; Vygotsky, 1978). In addition to the inherent motivational effect of gaming, Prensky (2003) also mentioned that the social interactions exhibited during game play, from the perspective of social constructivism, could facilitate students' knowledge gain.

With the development of technology, games are more often taking digital forms, so the strengths of game-based learning need to be transferred and applied into digital formats. In particular, playing video games has become popular nowadays among various populations across gender and age demographics (Entertainment Software Association, 2015). It seems necessary to identify practical means of integrating game-based learning theories into digital games.

Video games represent a major source of entertainment for both children and adolescents. A national survey conducted by the Entertainment Software Association in 2015 indicates that more than half of Americans play video games (Entertainment Software Association, 2015). The familiarity and popularity of the new generation of students playing video games also encourages educators to implement digital games as a medium for game-based learning to improve students' learning achievements (Prensky, 2003).

The limitations of digital game-based learning (DGBL). Although digital games have the potential to motivate contemporary students in learning processes, the implementation of digital game-based learning (DGBL) in conventional classroom settings is still difficult (Kirriemuir & McFarlane, 2004; Prensky, 2007). One of the reasons is the scarcity of engaging video games for teachers to use in the classroom (Prensky, 2007). Because of the high cost and technical expertise necessary to produce high-quality educational video games, teachers and educational institutions instead have to use existing commercial off-the-shelf (COTS) video games or "serious games", which are designed for educational purposes, to accommodate their pedagogical needs (Kim, Park, & Baek, 2009; Van Eck, 2006). Using existing commercial or educational games, however, cannot completely meet the needs of existing curricula. For example, CReSIS's online interactive animation was designed based on existing hands-on activities. It is difficult to use an existing video game that can perfectly meet the educational needs of the original curriculum. Thus, this research attempts to use more flexible ways of applying game mechanics and game dynamics, such as reward structures and social interactions, to gamify an existing animation.

The game-play behaviors and preferences among boys and girls can be different (Kinzie & Joseph, 2008); therefore, gender differences can pose another problem regarding the implementation of digital games into educational settings. These gender differences could affect the psychological effects of video games (Papastergiou, 2009). The way in which to apply

DGBL in a flexible way to fulfill various needs among boys and girls is a challenging question for the researchers in this field to address.

Gamification. Gamification is a new concept that refers to applying game mechanics in nongame applications (Deterding, Dixon, Khaled, & Nacke, 2011; Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011; Johnson et al., 2013). In various fields of business, particularly marketing, gamification has been employed successfully by a number of mobile applications and social media companies to increase users' engagement and to promote certain behaviors (Johnson et al., 2013). Its motivational effect can be useful in a variety of other fields and applications. The use of gamification in education can possibly increase positive emotions by applying various forms of game mechanisms in promoting students' learning achievements (Kapp, 2013). For example, the reward and reputation systems, such as point gain, level-up avatars, and leader boards, can improve learners' extrinsic motivations and engage learners in a meaningful learning process (Kapp, 2013).

With the flexible use of game elements into instructional settings, educators could customize the lesson activities based on students' needs and diverse demographics, including the potential gender differences related to the games' learning effectiveness and motivational appeal. By doing so, DGBL can be used to more effectively improve students' learning performances, regardless of students' gender, by exploiting effective and motivational instructional methods.

The initial step of this research is to utilize the educational potentials of gamification by adding reward and reputation systems as appropriate reinforcements for embedded values of learning motivations into current animation (Stipek, 1993). Furthermore, implementing social communications in reward and reputation systems facilitates social interactions that promote the development of individual valuation of learning content among learners to enhance these learners' intrinsic motivation (see Table 1). Given these gamification processes, educators can be afforded more flexibility in applying the concepts of DGBL into an instructional application to allow it to serve as a valid teaching–learning tool.

Table 1

The Design of Social Gamification in a Web-Based Animation

Gamification Strategy	Different Types of Motivation
Reward and reputation systems	Extrinsic motivation
Social communicative functions (e.g., chat room)	Intrinsic motivation

Social Gamification

Besides improving motivation, the social gamification in this research attempts to resolve another common problem that exists in most distance educational applications: the lack of interaction between the learner and the teacher, as well as among learners (Moore & Kearsley, 2011). To minimize these drawbacks, this research, based on social constructivist perspectives, suggests that applying group rewards in the animation could motivate students to work together (Yueh & Alessi, 1988). Thus, the design of gamification in the animation, in addition to integrating the reward structures of games, also integrated social-sharing functions that allow students to communicate with others during gaming processes. This social interaction compensates for the lack of interactions with teachers and among peers in distance education and, consequently, can engage students in the learning materials to improve their learning performances (Moore, 1989).

This research will implement leaderboards and other incentives to motivate students, while also providing an online chat room function to create an engaging learning environment. With the implementation of the online chat room, students could interact with others via conversations to exchange their thoughts in their learning processes.

The entire system was designed by AT and computer-supported collaborative work (CSCW) models to verify the importance of environmental affordances correlated to cooperative-work arrangement in online settings. Peer and human–computer interactions through the social activities in the gamified animation will be examined and will determine whether, or to what extent, sociocultural effect has an impact on students' learning performances. In addition, the results could propose a framework of social gamification for instructional designers to bridge the theory-practice gap in gamification of distance education. Table 2 summarized the implemented game elements in this study to socially gamify the animation.

Table 2

Gamified Features Used in the Study

Game Mechanics
Reward and Reputation Systems
• Leader board, score points, prizes, and level ups
Social Function
• Online chat room

Statement of Problems

To provide better educational services for the public, the CReSIS education team has developed an online digital interactive animation for distance education to promote content acquisition and to engage more teachers and students in the CReSIS outreach programs. The design of the animation is based on multimedia learning principles that attempt to reduce users' cognitive loads. The design of visual representations keeps students' attentions on the learning content; however, the previous assessment of the animation indicates that it cannot improve students' content knowledge of glaciers in comparison to lecture and mixed teaching methods, which include both animation and teachers' instruction.

Based on CReSIS researchers' reports, one of the reasons for students' poor academic performances might be students' lack of willingness to learn. The animation was designed to reduce users' cognitive load, which in turn provided learners room for critical and reflective thinking related to learning content. If students can use the freed cognitive abilities to expend additional effort on constructing new knowledge, they may be able to demonstrate higher levels of academic performance. The user-friendly animation by itself, however, cannot guarantee the freed cognitive capacity needed in learning attempts.

The expected learning effort heavily relies on students' self-regulation. Motivation is one of the psychological requisites of active participation in online learning. To improve CReSIS animation regarding the improvement on students' motivations and engagement, related research on contemporary students' attitudes and behaviors is needed. New generations of students growing up with technology are different from the people that our educational system was designed to teach (Prensky, 2007). DGBL provides the same digital language that this new generation of students uses to communicate with the world; however, the cost of technical sophistication hinders the development of DGBL in pedagogical settings. Another concern related to DGBL would be determining how to fulfill different needs of gaming practices and preferences between boys and girls to ensure DGBL results in the same instructional effect for both genders.

Gamification, a new trend in the video game industry exemplifying both the motivational power of games and the active behavioral mechanisms in play, has the potential to provide feasible ways of applying DGBL into current curriculum design. Educators can gamify learning content and activities to motivate students. This modification can also satisfy students’ needs across genders. Once the gaming process motivates students, the concern will be knowing how to sustain this motivation and to then transform it into learning attempts.

Grounded in SDT and previous eLearning research, the affordances of personal and social interactions that boost learning efforts could be used to promote students’ intrinsic motivations. Since these social interactions lie at the heart of forming a constructivist-learning environment in distance education, a key question arises: How could the possible use of gamification improve social interactions and feedback, which are scarce in distance learning situations, to improve learning performances?

To answer that previous question, this research proposed adding social functions into reward systems to gamify the animation in which peer interactions can assist students in transferring their motivations to active learning; however, social gamification is a relatively new concept in education, wherein there is a gap between research and practice. Thus, this research-integrated AT and CSCW develops into the social gamification of an existing online animation to bridge the theory-practice gap in educational gamification. The outcome also could provide a practical application of social gamification in promoting KU CReSIS outreach programs.

Significance of Study

Hypothesis. This research formulates hypothesis based on the findings of the previous study that evaluated the effectiveness of a web-based animation on middle school students' learning performance. The fundamental hypothesis underlying this research is that practical application of social gamification in an online educational setting is likely to enhance student intrinsic motivations and engagements, which would, in turn, improve students' learning performances.

Research questions. To verify the hypothesis, this study first attempts to examine the effect of social gamification in students' learning performances by looking at the changes between students' pre- and post-test scores under three instructional methods: online animation (control group), gamified animation, and socially gamified animation. The follow-up question further examines whether this effect yields greater benefits on students' higher levels of critical thinking and knowledge construction or on their rote memorization of the content.

The second part of the study attempts to address the psychological effect of social gamification in online learning environments. It examined students' emotional statuses based on three instructional methods to verify whether the use of social gamification could better promote students' positive emotions in their learning process.

The final study analyzed the relationship between students' psychological statuses and learning performances based on instructional methods. The analysis of this study could assist researchers in determining whether students' emotional changes in social gamification are related to their learning outcomes. The following are six research questions that needed to be answered in this study.

1. Is there a significant difference in gain scores from pretest to post-test relating to students' gender based on three different instructional methods: animation, gamified animation and socially gamified animation?
2. Is there a significant difference in gain scores between test question items relating to retention and test question items relating to transfer as it relates to the three different gamified instructions?
3. Can the survey used in this study predict students' motivation and cognitive engagement?
4. Is there a significant difference between students' motivation and cognitive engagement based on three different gamified instructions?
5. Is there any relationship between students' psychological statuses, in terms of motivation and cognitive engagement, and their test scores?
6. Is there a significant difference related to the correlation between students' psychological statuses, in terms of motivation and cognitive engagement, and learning performances based on the three different gamified instructions?

Limitations of the Research

While this study attempts to identify and to verify the effectiveness of using social gamification as a method in developing eLearning tools, some constraints and possible influences need to be highlighted to ensure the quality and significance of the research results.

The limits of developing the social gamified system.

- The selection of multimedia tools is limited to the animation, so the effects of social gamification may not be able to be applied to other types of multimedia tools.

- Because of the complexity and time requirements involved in designing and developing gamification, this research uses only social and reward functions from game mechanisms as the intervention. Other game elements, such as personal identity in a virtual world, also need to be examined to strengthen the validity of gamification in distance education.

The limits of experimental design.

- The student participants in this study were limited, coming from Lawrence, Kansas, and the greater Kansas City area. Their similar backgrounds may affect generalizing the results to different areas. Subsequent research will need to recruit more participants from different areas or even different countries.
- Research design was constrained by the schedule of the schools or organizations. Limited experimental time forces participants to complete multiple tasks in a short period of time, which may affect the reliability and validity of the results.
- The number of participants was difficult to control. Although this study was supported by CReSIS at KU, the education program at KU CReSIS cooperated only with a small number of schools and organizations in Lawrence and Topeka, Kansas, and the greater Kansas City area. In addition, the experimental studies lasted only about 3 months. The short period for experiments and the small number of school participants limited the sample size for this study.

Chapter 2: Literature Review

Educational Outreach

The nation's growing need for qualified scientists is increasing, but the supply is insufficient. Recent reports concerning higher education indicate that the attrition rates for college or associate degree students in science, technology, engineering, and mathematics (STEM) fields were, respectively, 48% and 69% in 2009 (Chen & Soldner, 2013). The U.S. government has noticed that higher attrition rates of science-related majors in college will result in a scarcity of scientists and thus affect the ability of the country to maintain its competitive position in the world. As a result, the government has invested time and effort improving students' knowledge and skills related to STEM fields while also attempting to produce more qualified scientists and engineers (Holdren, Lander, & Varmus, 2010; Langen & Dekkers, 2005).

In response to the decline of science-related professionals, the education system has assisted the development of scientific knowledge for students. According to a report conducted by the U.S. Department of Education, efforts made over the last several years in science achievement indicate that fourth graders are improving and becoming more competitive in comparison to other countries (Provasnik et al., 2012); however, this academic achievement in science is unevenly distributed. Students in some areas of the United States outperform students from other areas in this country in regard to their science capacities. Students in affluent areas, where schools can provide better instructional materials and services, including books, computers, technological support, and supplies, usually demonstrate better academic performance in science-related fields (Mullis, Martin, Foy, & Arora, 2012).

Widespread support for high-quality science instruction will be necessary to create equal-opportunity education for a diversity of students (Warren, Ballenger, Ogonowski, Rosebery, &

Hudicourt-Barnes, 2001). Thus, in addition to supporting conventional science education, the government also encourages professional scientists to get involved in science outreach interventions, which provide students with learning opportunities to improve their science-related knowledge and skill development (Nature Publishing Group, 2009).

An increase in the number of research-based science centers and organizations involved in educational outreach program efforts is occurring (Rosendhal, Sakimoto, Pertzborn, & Cooper, 2004). The CReSIS at KU is a science and technology center funded and established by the National Science Foundation in 2005. KU CReSIS has been involved in efforts to improve public scientific knowledge regarding polar science. The education team at CReSIS integrates the center's scientific findings into pedagogical settings by designing a series of inquiry-based activities, face-to-face presentations, workshops, and eLearning materials such as multimedia instructions, online games, and eBooks to promote teaching and learning related to polar science.

These outreach programs improve knowledge delivery and provide materials and tools for teachers to facilitate their teachings in schools (Nature Publishing Group, 2009); however, because of the limited time and resources, most centers such as CReSIS cannot provide frequent visits and trainings to expand the effect of these outreach programs (Jiang & Freeman, 2011). Therefore, the education team at CReSIS strives to use online resources as supplemental tools to provide better services in the wide delivery of comprehensive science knowledge for students while encouraging more teachers to integrate these materials and activities into their curricula.

According to national reports, however, only a small percentage of teachers have taken advantage of and incorporated online resources into their teachings (Nature Publishing Group, 2009). Teachers are unfamiliar with these digital tools and question their effectiveness. Most teachers still prefer on-site, face-to-face presentations given by scientists or representatives of the center as a way of introducing science in their classrooms (Nature Publishing Group, 2009). In order to efficiently use the center's resources and encourage teachers to implement digital tools in their curricula, this research provides teachers evidence with regard to the efficacy of using eLearning tools to improve science education. In addition, the national report regarding student achievement in science indicates that improving middle school students' science achievements is a relatively difficult task because longitudinal studies of math and science achievement often show little increase in student achievement on test scores despite various efforts of schools. In addition, this relatively low level of math and science achievement at the fourth-grade level could be an indicator of a low level of motivation toward scientific disciplines (Mullis et al., 2012; Provasnik et al., 2012; Woods, Kurtz-Costes, & Rowley, 2005). Thus, this study will focus on fourth, fifth, sixth, seventh, and eighth graders with the goal of forming their knowledge and expertise in polar science.

Concerns of eLearning

The education team at CReSIS believes that technology-mediated distance learning in some instances is necessary, especially for outreach programs that are aimed to widely disseminate educational information to the public. However, teachers' attitudes towards technology as well as concerns related to technology's effectiveness in addressing learning achievement are major barriers to the advancement of eLearning (Ertmer, Paul, Molly, Eva, & Denise, 1999; Moore & Kearsley, 2011; Prensky, 2007).

Teachers' attitudes toward digital technology. Contemporary students growing up with computers, video games, smart phones, and other digital tools are different from older generation teachers who never expected digital technology to emerge or to become an integral part of their lives (Prensky, 2007). These teachers as a whole still think learners should be taught using traditional strategies, such as didactic teaching through step-by-step instruction from textbooks, which may hinder students' motivation and minimize their learning potentials (Prensky, 2001, 2007). When the learning content and course activities are presented in a way that students are more familiar with, they could become more engaged in the learning process (Conole, De Laat, Dillon, & Darby, 2008). Thus, the use of technology as an instructional strategy could motivate students to actively participate in the course activities.

Additionally, the ubiquity of technology has influenced today's students' ways of thinking and communicating with the world (Prensky, 2007). They receive information quickly and prefer multitasking, which allows them to randomly access a variety of information at the same time (Prensky, 2001); however, these new characteristics of digital-generation students often lead to the belief on the part of teachers that technology contributes to shorter student attention spans when the technology is used in education (Barnes, Marateo, & Ferris, 2007). Skeptical teachers believe that the students' lack of attention is attributable to the use of technology, but recent studies have indicated that these concerns about technology are unfounded because students' short attention spans result mostly from tedious and static learning processes (Prensky, 2001). On the other hand, the appropriate implementation of technology can increase students' motivation and engage them in active learning (Dalgarno & Lee, 2010; Huizenga, Admiraal, Akkerman, & Dam, 2009; Prensky, 2007).

The lack of effective classroom interactions. Another drawback of eLearning is the lack of teacher–student and student–student interactions (Moore & Kearsley, 2011). Distance education, unlike conventional classroom instruction, is relatively ineffective at nurturing close relationships between teachers and students, and it is also ineffective at nurturing a spirit of teamwork among students. Social constructivists believe that the development of knowledge is a collaborative activity situated within an environment where its cultural and social factors will affect learners' cognitive capacities, such as perceptual capabilities as well as attention and memory, in constructing knowledge (Kim, 2001; Vygotsky, 1980). Lev Vygotsky also emphasized the importance of positive interactions between a teacher and students in improving students' understanding of instructional materials, which lead to greater academic success. Teachers in classrooms not only facilitate the transmission of knowledge to students but also support students' continuing efforts to construct new ideas or concepts during the learning process (Driver, Newton, & Osborne, 2000). Accordingly, the contextual affordances of physical classrooms can benefit students in forming new knowledge and improving academic achievement.

Unfortunately, positive interactions between teachers and students, as well as the interactions between students, are difficult to maintain within digital-distance learning contexts (Moore, 1989; Moore & Kearsley, 2011). Since these positive interactions between teachers and among peers lie at the heart of forming constructivist-learning environments, possible improvements in teacher–student and student–student relationships will affect the use of eLearning in current pedagogical settings.

Cognitive Load in eLearning

In addition to the lack of social interactions in digital-distance learning, the use of multimedia tools also raises the concern about overwhelming learners' cognitive loads (Mayer, 2005a; Mayer & Moreno, 2003). For example, the dynamic representation in animation requires students to demonstrate a substantial amount of cognitive skills to comprehend the causal or functional process of the phenomena in the learning contents (Betrancourt, 2005; Mayer & Moreno, 2003). For another example, while watching the retreat of glaciers in the animation, students within this shot period of time need to pay attention to multiple domains such as the change of temperatures, sea-level rise, and other relevant phenomena to wholly understand the content and to construct new knowledge. This learning process may overload students' cognitive abilities. They need more mental efforts to construct a series of mental schemas for constructing knew knowledge, especially when learners perform unfamiliar learning tasks in the process of engaging with the animation. Based on John Sweller's cognitive load theory, within this process of learning attempts, the interaction between limited working memory and organized existing information stored in long-term memory may lead to the risk of cognitive overload (Sweller, 2005; Sweller, Van Merrienboer, & Paas, 1998).

In order to maximize the effectiveness of distance education, the design of eLearning tools should minimize learners' cognitive loads. The total cognitive load is the amount of *intrinsic*, *extraneous*, and *germane* cognitive load (Sweller, 2005). The *intrinsic* cognitive load corresponds directly to the difficulty level of learning subjects, while *extraneous* cognitive load can be affected by how the learning materials are designed and presented (Sweller, 2005). A well-designed eLearning tool can control these two types of cognitive load by effectively presenting appropriate information that meets learners' skill levels (Sweller, 2005; van Merrienboer & Kester, 2005). Once learners minimize cognitive load of manipulating the learning environment, they can free their working memories, which allows them to better focus on learning tasks. When learners interact with learning tasks, they will engage in appropriate cognitive processes to organize relevant information and to form new knowledge. These efficacious learning processes lead to an increase of *germane* cognitive load. Unlike intrinsic and extraneous loads, germane cognitive load reflects learners' efforts that contribute to knowledge gains (Chandler & Sweller, 1991; Sweller, 2005; Sweller et al., 1998). In other words, the design of multimedia tools should not only improve the usability of the tools to reduce intrinsic and extraneous load but also should contribute to improvements in students' learning attempts that would in turn increase *germane* cognitive process.

Multimedia Strategies

With attempts to improve the effect of multimedia instruction, the constructivist eLearning approach necessitates providing learners with appropriate scaffolding to reduce learners' cognitive load while using the tool and also engaging them in the learning process to promote active learning (Mayer, 2005a). A common way of reducing cognitive load is to improve content delivery and to free a learner's working memory on constructing new knowledge. For example, Dr. Mayer, professor of psychology at the University of California, Santa Barbara, proposed multiple design principles based on cognitive theory of multimedia learning to effectively deliver learning contents and to exclude extraneous processes to reduce extraneous cognitive load (Mayer, 2005a, 2005c, 2005d). Consequently, learners have sufficient working memory to interact with essential information and to form a schematic knowledge stored in long-term memory for the future use of new knowledge construction.

Successful learning, however, still relies on students' efforts on actively participating in the learning process. Effortful learning leads to the construction and automation of schemata stored in long-term memory for future use (Sweller, 2005). Some instructional strategies for eLearning could support the increase of learning efforts. For instance, use of the self-explanation approach when studying worked examples improves learners' metacognitive skills and allows them to mentally integrate the information from the examples to form a schema of new knowledge. This new schema in turn serves as a central executive mechanism related to working memory to reduce total cognitive load (Roy & Chi, 2005). In addition, this practice provides an optimal level of germane cognitive load so that learners can be actively engaged in the learning process.

Although eLearning strategies can reduce unnecessary cognitive load and encourage learners to internalize the knowledge given when learning through the multimedia instruction, the success of these strategies in unstructured open-learning environments, such as distance education, without established regulations related to interactions in conventional classrooms will rely on learners' self-regulation and self-determination (de Jong, 2005; Renkl, 2005). Accordingly, the high-quality distance-learning system, besides simply facilitating content delivery, also necessitates improving students' self-discipline. According to SDT, sociocultural interactions in learning environments could improve students' intrinsic motivation, and these interactions as external regulations can be used to encourage students to actively participate in learning processes, which in turn results in successful online learning experiences (Moore & Kearsley, 2011; Ryan & Deci, 2000a).

Motivation and Engagement

The current practice of eLearning is limited by learners' self-regulation and self-determination (de Jong, 2005). Therefore, the implementation of technology should lead to a greater degree of active participation in online distance-learning contexts. In order to do so, much research is needed to understand the underlying motivation for self-determination in online distance learning.

Previous research suggests that the preliminary step to educating children is to hold their attention (Prensky, 2007). Many instructional strategies, such as assigning rewards to learning tasks, motivating students' interests about the learning context and encouraging them to engage themselves in the learning process (Gagné & Deci, 2005; Thorndike, 1927), have been identified within the literature; however, within the literature, these motivators, located outside the individual, are too often considered in isolation to other motivating factors. Grounded in cognitivism, extrinsic motivation toward learning subjects, compared with intrinsic motivation, is insufficient and will quickly dissipate (Ryan & Deci, 2000a, 2000b). Even worse, in some instances, extrinsic rewards can undermine intrinsic motivation and can reduce student autonomy because students' learning efforts wholly rely on tangible rewards (Ryan & Deci, 2000b). Thus, it is critical to internalize a student's extrinsic motivation, which will in turn enhance a student's self-discipline over time within digital online learning.

With regard to increased intrinsic motivation, self-determination theory (SDT) indicated that this positive emotion is correlated to the fulfillment of human needs (Deci & Ryan, 2011; Ryan & Deci, 2000a). Beyond basic physiological needs such as food and shelter, it is important to develop self-esteem and self-actualization among students during the learning process in order to form students' self-regulation and self-determination (Maslow, 1943). In turn, students are able to internalize and integrate the value of learning tasks toward positive learning behaviors. To do so, the design of pedagogical settings based on SDT should fulfill students' three innate psychological needs: competence, autonomy, and relatedness (Deci & Ryan, 2011; Ryan & Deci, 2000b).

The principles of SDT also claim that sociocultural factors within learning environments could permit the balance between students' competence, autonomy, and relatedness, resulting in active self-directed learning (Deci et al., 1991). Accordingly, the digital distance education should not only improve learners' intrinsic motivations but also should implement social interactions to externally regulate students' positive learning behaviors to develop autonomy and self-discipline toward learning tasks in an online learning environment.

Digital Game-Based Learning (DGBL)

In addition to the instructional strategy to improve intrinsic motivation, it is also necessary to realize which learning media would most motivate and engage today's students. As mentioned previously, contemporary students consider digital technology as an integral part of their lives, and the ubiquitous use of technology also has influenced their ways of thinking and communicating with the world (Prensky, 2007). Thus, conventional instructional tools designed for the previous generation students may be insufficient in promoting motivation and engagement among contemporary students (Palfrey & Gasser, 2013; Prensky, 2007). Digital games within all digital technologies have become a popular form of entertainment for contemporary students (Squire, 2003). The enjoyment resulting from gaming has great potential of facilitating student motivations. The nature of cooperation and competition in playing video games could also facilitate the formation of active learning communities.

Modern digital trends have changed the demographics of playing video games, which have become popular for various populations across genders and ages. A national survey conducted by the Entertainment Software Association in 2014 indicated that 59% of Americans, including 52% of males and 48% of females, play video games (Entertainment Software Association, 2014). Transcending the stereotype of the teenage gamer, video games also have become a highly popular form of entertainment among American college graduates, who, according to recent studies, spend over 10,000 hours playing video games per year (Prensky, 2001). Because students today are different from the students for whom the educational system was originally designed, pedagogical approaches should change and adopt new instructional methods to meet the new generation's needs and its learning styles (Prensky, 2007). The familiarity and popularity of video games among this current generation of students inspires educators to implement digital games as a way to motivate and engage today's students in the learning process.

The Nature of Fun

Gaming can be perceived as an enjoying process in which the player's interests or amusements are inherent to the fulfillment of each task (Gee, 2005; Prensky, 2007; Squire, 2003). This nature of fun could be applied in education as an intrinsic motivator for improving student engagement within the learning process. The research of DGBL indicates that the characteristics of a well-designed DGBL could improve students' learning interests involving complex learning and could engage them in the problem-solving process to construct new knowledge (Gee, 2003, 2005). The increase in motivation will lead to a higher number of learning attempts and self-determined efforts to help students stay active in the learning process (Berger & Karabenick, 2011).

Motivation in DGBL

If this motivation cannot be linked to students' mental needs, however, then the students can be easily disturbed by external factors; students in turn would not be able to remain in the same learning condition for a long period of time (Ryan & Deci, 2000b; Stipek, 1993). Thus, motivation and engagement resulting from enjoying video game play, though affording certain enhancement to conventional modes of learning in certain regards, is nevertheless still inadequate for autonomous learning. Students need external regulations to facilitate the internalization of those motivations to attain deeper engagement in learning contexts.

The SDT indicates that social-contextual factors have the potential to strengthen intrinsic motivation. The contextual affordances of learning environments, such as social interactions among players, can internalize the value of challenge and problem-solving within gaming. Group affiliation that encourages students to compete or cooperate with others will result in an active-learning atmosphere (Ryan & Deci, 2000b). In addition, the satisfaction of belongingness and connectedness with others will motivate students to learn to develop their competence through the autonomous learning process in game play (Ryan & Deci, 2000b).

Gamification

Although DGBL has the potential of improving digital-distance education, inadequate technology infrastructures and supports reduce schools' willingness to embed DGBL within learning environments (Hilton & Honey, 2011; Prensky, 2007; Van Eck, 2006). Teachers without school support experience difficulties in implementing digital games into their pedagogical settings. Moreover, producing high-quality educational video game is prohibitively expensive with respect to most teachers (Johnson et al., 2013). Thus, teachers need an alternate way of applying the instructional strategies of DGBL and of adjusting it to meet their teaching goals (Kim et al., 2009). The traditional methods for DGBL rely on taking advantage of existing contents of COTS video games to meet teachers' educational purposes or choosing a suitable educational game designed for specifically learning a subject that meets teachers' needs (Van

Eck, 2006); however, these approaches, based on existing games, reduce the flexibility of implementing the concept of DGBL into the curriculum. Therefore, the lack of a feasible and cost-effective way of applying DGBL into pedagogical settings will hinder its educational effectiveness.

The modern game industry and service marketing started applying a new game-like service called gamification to enhance users' engagement (Huotari & Hamari, 2011). The main concept of gamification uses game-design elements in nongame contexts to improve user attention and behavior (Deterding, Sicart, et al., 2011). The experience of gaming is believed to produce joy of use, engagement, and other positive emotions while using the software or its services (Deterding, Dixon, et al., 2011; Deterding, Sicart, et al., 2011; Huotari & Hamari, 2011). Accordingly, the use of game elements in instructional tools should be able to make it enjoyable and engaging. Thus, the application of gamification to eLearning content holds the same potential promise of DGBL to improve students' motivation toward learning.

Another advantage of using gamification is its flexibility in curriculum design. Unlike producing a new video game, gamification only requires modification of the structure of current nongame products and services to provide users a similar experience to gaming (Deterding, Dixon, et al., 2011; Deterding, Sicart, et al., 2011). For example, the application of gamification to e-learning content can motivate users to engage with the content by adding reward and reputation systems with points, badges, leader boards (PBLs), and levels. These strategies not only meet learning objectives but also increase the efficacy of the developing process. From an educational perspective, structural gamification, which modifies existing instructional tools based on the satisfaction of students' psychological needs regarding their learning motivations and engagement, can provide schools and teachers more flexibility in applying the concept of DGBL into pedagogical settings.

This flexibility could also facilitate the learning effectiveness of DGBL by eliminating the gender differences in game activity preferences. Boys and girls generally have different preferences of games modes. For instance, boys tend to be more interested in competing with others in action games, but girls prefer cooperation with others during game play in social games (Entertainment Software Association, 2015; Papastergiou, 2009). The differing appeal of game modes could increase the difficulties to create the educational game that fulfills everyone's needs (Kinzie & Joseph, 2008). By applying the strategies of gamification, instructors would have more flexibility to implement various game mechanics to compensate the gender differences in game activity preferences.

The Design of Social Gamification in Distance Learning

Since learning is more complex than other human behaviors, such as shopping, simple increases in motivation and engagement cannot guarantee the success in learning achievement. Students need to exert efforts in the learning process. Therefore, the engagement and motivations associated with gaming need to be applied to learning contexts. According to SDT and social constructivism, social-contextual factors could be useful external regulations in strengthening students' positive emotions during the learning process, especially in an online learning context. Thus, in addition to the implementation of game elements, these social aspects are also critical to improving the effectiveness of instructional tools in distance education.

Activity Theory (AT). The AT provides a framework (*Figure 1*) for analyzing students' needs and social cultural relationships in a learning environment (Savery & Duffy, 1995), which can be used in applying social and cultural context to gamification design. Activity theorists consider activities as basic units of analysis in human–computer interaction research (Kuutti, 1996). Participation in different activities creates consciousness, and the contextual affordances in the environment facilitate teamwork or other social activities in completing tasks. The use of tools in the theory serves as a mediator to facilitate the working process (Kuutti, 1996). Vygotsky (1980) also mentioned that human interactions with environments exist through the use of tools and signs. Users with positive experiences related to use of supplemental tools exhibit increased individual motivation in completing the tasks. In addition to these perspectives related to the importance of tools, the AT model incorporates concepts related to community, rules, and division of labor as mediators of human activity. That is, the social environment provides constraints within the community, for example, working rules, cultural norms, and notions of teamwork, which correspond to the use of tools, also affect people's performance**.**

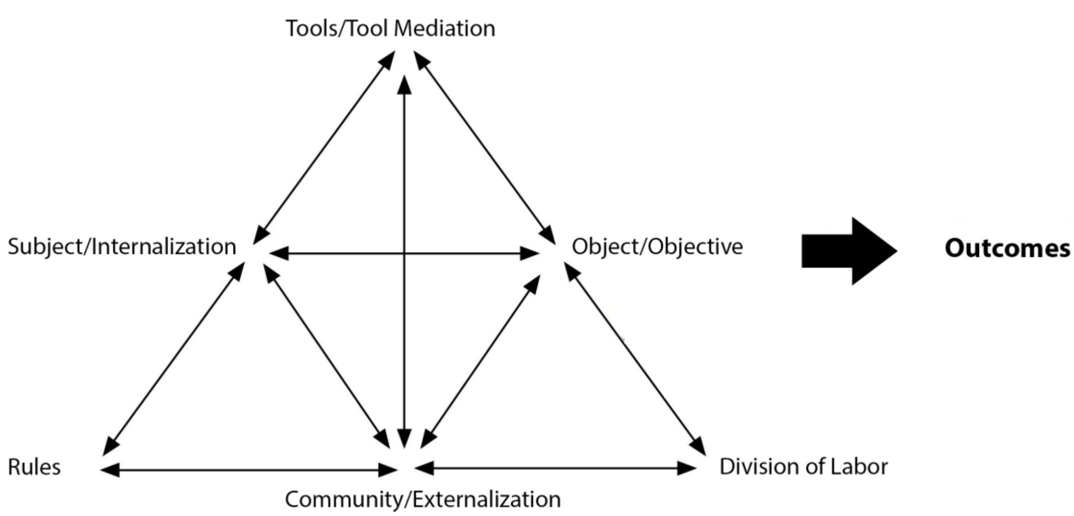

Figure 1. Diagram of the Activity Theory model.

Computer-supported collaborative learning (CSCW). Although AT has provided the system model of expended theory of activity between users, tools, and environments, there is an insufficient use applying the standard method or guidelines for using AT to design instructional tools (Mwanza, 2000). To develop a computer system for supporting collaborative learning in distance education, a substantial amount of further research that can bridge the gap between research results and practical design is needed. Some strategies related to CSCW could guide the use of digital tools that are capable of assisting students to satisfy their learning goals through positive social interactions in the virtual environment. For example, an environment integrated with social networking qualities, such as cooperation, competition, and content sharing, could improve the working performances of its users. Thus, in addition to developing a system that can provide feedback and reward users with their developing progress, this project proposed implementation of a gamified system that would also allow community members to communicate with each other during the gaming process, which, in turn, would improve their learning performances.

Other game-design principles. Other design principles have been exemplified by the game industry within efforts to design a different set of play experiences associated with positive emotions. These design principles, associated with positive learning experiences, can also be integrated within implementation of social gamification in educational fields. For example, Four Keys to Fun proposed by XEODesign identifies four types of gaming experiences in playing video games: easy fun, hard fun, people fun, and serious fun (Lazzaro, 2004). Easy fun attracts players' attentions; hard fun provides challenges to win a reward; people fun results from social interactions and creates opportunities for competition and cooperation; and serious fun involves changes in players' internal states during and after gameplay through applying personal meanings into the context of the game (e.g., role play as a city's mayor involves use of various strategies to reduce the air pollution in corresponding the player's beliefs in environmental issues). For educational purposes, some experiences such as serious fun and people fun may be more appropriate and effective in internalizing the value of gaming context while also forming an online collaborative learning environment.

Csikszentmihalyi's flow theory (1990) provides another framework for designing gameplay that supports players in an active condition during the gaming process. A well-designed video game should allow players to stay in flow states where players' activities are not for rewards but for the exhilaration of the process (Squire, 2003). To reach such an optimal experience and to make learners completely involved in the gaming process, the tasks should be designed in a proper sequence according to the skill level of a player. The easier tasks should be arranged before more difficult subtasks, and these tasks are based upon the same body of knowledge (Clark & Mayer, 2011). Using this progressive design of gameplay, students could be more engaged in learning activities while using the socially gamified system.

Other principles, such as Janaki Kumar and Mario Herger's five-step approach for gamification, provide industry guidelines for developing engaging software or services, which fulfill users' authentic needs. These five steps includes knowing your players; identifying the mission; understanding human motivation; applying game mechanics; and managing, monitoring, and measuring the software (Kumar, 2013). Using these standards as a guide can assure the quality of designing and developing process of the socially gamified system. In addition, instructional designers applying these standards can better understand their users, including both teachers and students.

How to Measure the Effectiveness of Social Gamification

The use of social gamification in distance education aims at enhancing positive emotions regarding learners' intrinsic motivation and cognitive engagement while also creating a learning community with the ultimate goal of transferring newly gained motivation to learning efforts to improve students' learning performances. The assessment of interactions between students' learning performances and their motivations, cognitive engagements, and social interactions can validate the concept of using social gamification to facilitate learning achievement in online settings.

Motivation and cognitive engagement. To assess motivation that also reflects the engagement through the use of learning strategies, it is necessary to determine the appropriateness of the available instruments (Fredricks et al., 2011). The Motivated Strategies for Learning Questionnaire (MSLQ), developed by the researchers at the University of Michigan, is an instrument that can measure students' motivational orientations and their use of different learning strategies for a course (Pintrich, 1991). The MSLQ has been reviewed for evidence supporting its reliability and validity: Cronbach's alphas ranging from .52 to .93 indicate a strong internal consistency (Pintrich, 1991). The positive correlation between MSLQ subscales and students' final course grades also demonstrate its predictive validity (Pintrich, 1991). Accordingly, MSLQ is a reliable and practical instrument for measuring motivation and cognitive engagement.

Although the initial MSLQ was designed for assessing college students, it has currently been adapted for middle school students. The middle school version of the MSLQ contains 55 items in five subscales: self-efficacy, intrinsic value, test anxiety, cognitive strategy use, and self-regulation. The first three items are related to students' motivational beliefs, and the last two are relevant to student self-regulated learning strategies (Pintrich & De Groot, 1990). These items can be used to examine the impact of different instructional methods on student achievement, motivation, and use of learning strategies, which represent student cognitive engagement (Fredricks et al., 2011).

Collaborative learning. The other research aspect of this study was the social effect of social gamification in promoting collaborative learning. When evaluating the level of students' collaborative learning in socially gamified systems, some indicators such as types of learning activity, students' initiatives, regularities, and promotion teamwork, among others in online chat rooms, can be used to gauge the extent of collaborative learning that occurs within the learning process (Anaya & Boticario, 2009). Therefore, using students' conversations during gameplay would provide insights with respect to social interactions that contribute to the collaboration in an online learning environment. Thus, the number of messages sent and replied can be used as a quantitative indicator that can suggest which students are more active and collaborative learners (Anaya & Boticario, 2009).

Moreover, types of conversation demonstrate the relationship between a user's social interactions and collaborative learning (Santos, Rodríguez, Gaudioso, & Boticario, 2003). According to research on collaborative online learning, students' online messages can be classified into four categories: social, procedural, expository, and cognitive (Oliver, Omari, & Herrington, 1998; Santos et al., 2003). The social and procedural conversations are not directly linked to collaborative learning. In contrast, within expository and cognitive conversations, students exchange knowledge and discuss issues to better understand the content; these exchanges demonstrate higher levels of social interactions in collaborative learning (Santos et al., 2003). Therefore, more expository and cognitive conversations among students demonstrate the effectiveness of social gamification in the promotion of social interactions in an online learning environment.

Chapter 3: Methodology

Introduction

This study attempts to conceptualize and validate a research model (see *Figure 2*) for social gamification in multimedia instruction with the purpose of improving the quality of science outreach programs at CReSIS at KU. The framework assumes that positive emotions such as intrinsic motivation and cognitive engagement found in students are highly correlated with the use of game design in nongaming eLearning applications; this framework holds the position that game design in nongaming eLearning applications compensates for the lack of social interactions in distance learning. For example, the gamification of an online computer animation, which uses certain game elements and techniques, can elicit students' motivation and build a spirit of teamwork to improve learning performance. The use of social function such as online chat rooms regulates the newly gained motivation and transfers it into learning efforts to facilitate learning. This study proposes implementing reward structures and social networking services associated with game mechanisms to gamify an online digital interactive animation developed by the education team at CReSIS. A key purpose in conducting this study is to verify the reliability and validity of this applied theoretical model of social gamification in online education with the purpose of developing a practical eLearning tool to support the center's science outreach.

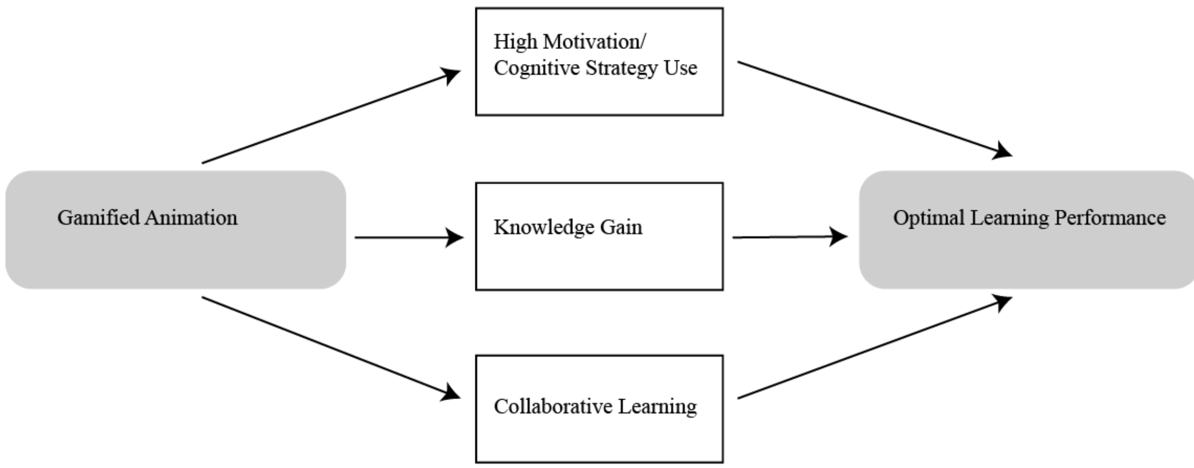

Figure 2. Proposed model

This study conducts three between-subject experiments to measure the effect of students' motivational orientations, cognitive engagement, and social interaction on their learning performances while engaging with CReSIS online animation with the purpose of learning basic knowledge about glaciers. The gamified animation was designed with two levels of gamification: one based on individual efforts to win PBLs, and another system that integrated not only this gamified animation but also an added chat room function to allow students to cooperate with others to win PBLs. These two levels of gamified animations were compared with the original instructional, which integrated CReSIS animation without gamification, to determine whether gamified eLearning instruction could better promote content knowledge of polar science. The second experiment looked at whether the use of social gamification could lead to a more substantial impact on students' motivation and cognitive engagement. The final experiment investigates the correlation of the previous two studies to examine whether students' emotional conditions would result in advanced learning performances. The intent of these three experiments was to determine whether the implementation of social gamification integrated with the CReSIS animation could enhance students' motivation and cognitive engagement, in turn facilitating the process of knowledge construction.

The foremost purpose of this research is to examine the relationship between gamification, motivation, cognitive engagement, and social interaction in open- and distance-learning settings. This research also develops a practical way of applying game elements into nongaming eLearning applications to motivate and engage students in learning activities in online settings. In addition, according to SDT, this increased motivation and cognitive engagement could be retained in the learning process by integrating social interaction; in turn, this active participation in the course activities would promote self-regulated learning to ensure students' success in online education. These findings can be also used to provide guidelines for developing gamified educational applications for distance education.

Procedures

The research conducted between-subject experiments, in which each student randomly underwent one of the three instructional methods (the original CReSIS animation without gamification, gamified animation, and socially gamified animation) to learn about treatment effects (learning performances and emotional orientations). Students' learning achievements were measured by gain scores on pre- and post-tests, and students' motivation and cognitive engagement were measured by mean scores on surveys. Because of time constraints, students answered the survey only one time at the end of the experiment, assessing their psychological status in terms of motivation and cognitive engagement after the lectures. Then, the researcher examined the mean score differences of these two indictors based on three instructions to identify and verify the emotional and academic effect of social gamification. The results can provide crucial data and insights related to the application of social gamification to eLearning tools with the aim of improving the effectiveness of distance learning in CReSIS science outreach programs.

Research Perspectives

This study was a quantitative study. It lasted from 2014 through 2016, and the data collection occurred from the fall of 2015 through the spring of 2016. The participants were recruited from the educational organizations that have partnered with CReSIS at KU. Three different levels of gamification were applied to the CReSIS animation and were used as the intervention to examine participants' emotional responses and their learning performances. The collected data include the survey results and the gain scores from pretest to post-test. A comparative analysis of the collected data was conducted.

Research Questions

This study was a quantitative study to analyze the differences between participants' improved grades from pretest to post-test and their survey scores. The first two questions were related to learning performances and focused on identifying whether social gamification could better promote students' content knowledge. Question three and question four attempted to verify the emotional effect of social gamification on the learning process. The last two questions looked at the relationship between students' emotional conditions and their learning performances while considering the differences in the instructional method. With these comparisons, this research could provide data-driven evidence to determine whether the implementation of social gamification could improve the effect of CReSIS animation in teaching polar science in online settings.

The following research questions were considered:

1. Is there a significant difference in gain scores from pretest to post-test relating to students' gender based on three different instructional methods: animation, gamified animation and socially gamified animation?
2. Is there a significant difference in gain scores between test question items relating to retention and test question items relating to transfer based on three different gamified instructions?
3. Can the survey used in this study predict students' motivation and cognitive engagement?
4. Is there a significant difference between students' motivation and cognitive engagement based on the three different gamified instructions?
5. Is there any relationship between students' psychological status, in terms of motivation and cognitive engagement, and their test scores?
6. Is there a significant difference about the correlation between students' psychological status, in terms of motivation and cognitive engagement, and learning performances based on the three different gamified instructions?

Participant Population

The participants in this study were students attending after-school programs, including the Boys & Girls Club in Lawrence, Kansas, and the Chinese School of Greater Kansas City in Kansas City, Missouri. These after-school programs had partnerships with CReSIS at KU. Based on science achievement reports, this study focused on students in Grades 4 to 8 who have the most trouble with science education in comparison to students in other grades (Provasnik et al., 2012). Therefore, the criterion for selection of student participation in this study was based on students' grade levels. Only students between age 8 and 13, in the fourth to eight grades, were invited to participate in this study.

Students who participated in the after-school programs that participated in this research study come from multiple neighborhood schools within the Lawrence, Kansas, and the greater Kansas City areas; these neighborhood schools reflect both affluent and high-poverty areas. The researcher worked with teachers and staff members there to disseminate flyers to invite student participants. If they agreed to participate in this study, parents or guardians were required to sign the consent form. The package of participant recruitment files are presented in Appendix A.

Students in this study learned the basic knowledge of glaciers through the multimedia instruction with three levels of gamification: the original CReSIS animation without gamification, the gamified animation, and the socially gamified animation. The learning materials were not related to their course work at school to eliminate the impact of prior knowledge on study results. Then, participants were randomly assigned to one of three treatment groups (animation, gamification, and social gamification group) to reduce variance. By doing so, students' personal backgrounds (gender, social status, religious belief, etc.) and level of technology use was controlled to achieve a closer match between the different treatment groups.

Intervention

To gamify the current CReSIS animation as an experimental intervention for this study, the researcher worked with ABen Tech Co., Ltd. (ABen Tech) in Taiwan to implement a reward system and online chat rooms within the original CReSIS animation. ABen Tech, a company with years of experience in creating simulation systems, provided the required skills to implement and to support the quality-integrated eLearning application needed for this study.

The prototype developed with ABen Tech comprised animation, gameplay, a reward system, and an online chat room. The students in the control group tried only the animation to learn the content knowledge of glaciers (*Figure 3*). The interface of the animation was designed in accordance to multimedia principles to improve its usability (Clark & Mayer, 2011; Hsu, 2012). The first experimental group used animation and then played the game and won rewards to review the content (*Figure 4*). This gamified eLearning system, which aligns with the game-based learning system, attempts to motivate students through the gameplay during the learning process (Prensky, 2007). The second experimental group participated in a similar instructional method as the experimental one group did, but they could use an online chat room to communicate with each other while playing the game (*Figure 5*). The major difference from the gamified animation in this iteration of socially gamified animation was the use of the online chat room. In this instructional system, social interactions in the online chat room, which is based on SDT, served as a regulation to assist students to transfer newly gained motivation into learning efforts (Ryan & Deci, 2000a).

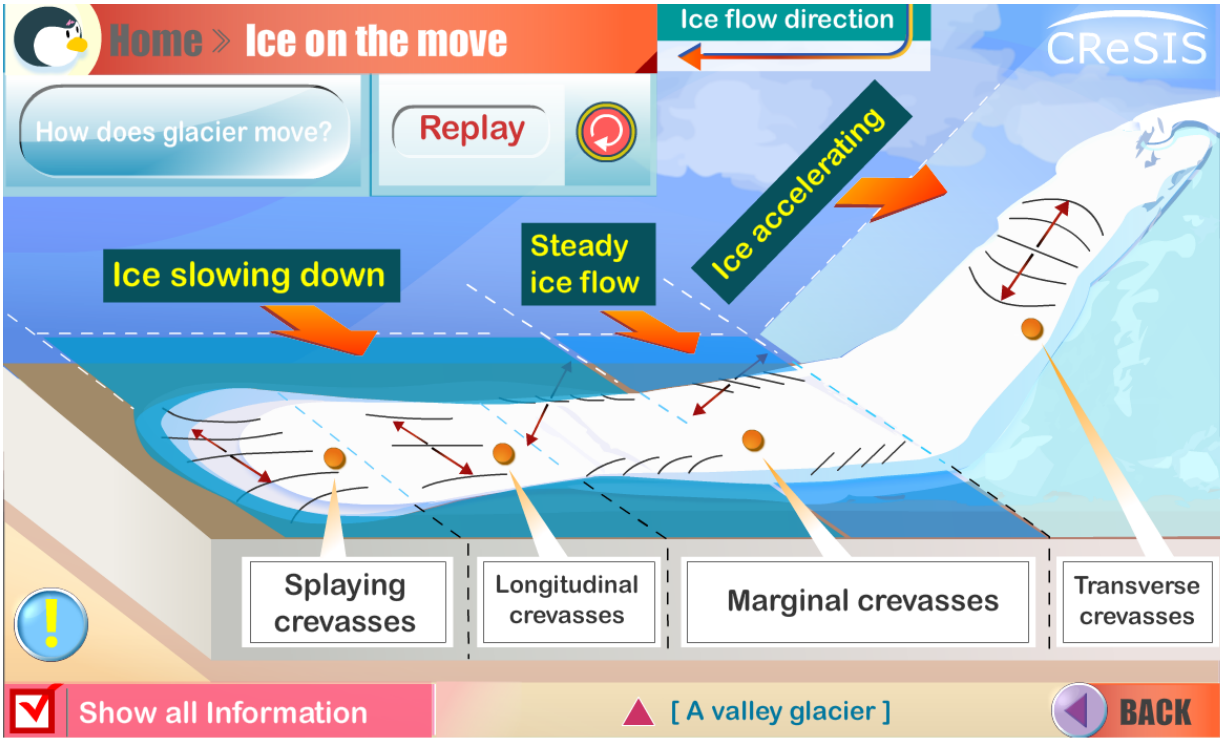

Figure 3. Effective interface design for learning efficiency.

Figure 4. Gamified animation to motivate students.

Figure 5. The use of an online chat room to facilitate the effect of the gamified animation.

In addition to assessing the learning effect of gameplay on the animation by comparing the differences between the two experimental groups and the control group, this study also attempts to verify whether the social factor in gameplay fosters the effect of gamification in multimedia instruction. By turning the chat room function off or on, this system could create two types of gamified animation to fulfill the study's needs. This research project would like to further explore students' social interactions, including completion and cooperation during the learning process, so that the competition in the leader board was considered as one type of reward structure instead of a social function. Therefore, the social gamification was clarified as a gamified animation with an online chat room function in which students' conversations could provide more information regarding the effect of social factors in the learning process.

The participants underwent these two types of gamified animation with and without the online chat room to evaluate the impact of whether gamification or social gamification could have advanced emotional and academic effects on students' learning performances in polar science. Then, the results were compared with the control group, in which students engaged with the original animation without gamification, to further identify the impact of social gamification on the CReSIS animation.

Socially gamified animation system. The socially gamified animation was designed and developed as an experimental intervention. In this gamified system, students learned the content knowledge by interacting with the animation for 20 minutes and then answered 25 questions randomly selected from the database to review the content and win points (see Appendix A for details about all 30 questions stored in the database). When answering the questions, one-third of the participants were allowed to use the chat room to communicate with others.

With the implementation of reward structures, this system attempted to capture and maintain students' attentions and to motivate them in the learning process. Their positive emotions (motivation and cognitive engagement) were examined with other elements (competition and cooperation) that could be identified within the online chat room to see whether sociocultural interactions in the learning process were correlated to students' emotional reactions and affected their learning performances.

Animation with reward structures. In order to examine the effectiveness of gamified applications with regard to students' motivations and cognitive engagements, the researcher adopted an existing computer-based narrated animation called Glaciers in Motion, which was developed by the education team at CReSIS, and modified it as a game-like eLearning application by adding reward structures. After interacting with the learning content, users answered 25 questions that were randomly assigned from the database (see Appendix A). These questions were presented to students in two formats: multiple choice and fill-in-the-blank questions. Users could win points, advance levels, and earn badges by successfully answering these questions. As a consequence of points being accumulated, students could achieve the top rank with honor.

In addition to representation of the students' achievements, a given point combined with a leader board and social networking function can be used to represent more than one dynamic phenomenon within this reward system. Chat history related to ranking and scoring, serving as an indicator of students' relationships and competition status, assisted researchers in investigating whether students' social interactions could contribute to optimal learning performances.

Question items and game-activity development. This research used the Next Generation Science Standards (NGSS Lead States, 2013) as a guideline for designing the lesson activities within the gamified system to develop high-quality, scientifically based instructional practices in polar science. First, the standards mandate the step of previewing questions at the beginning of each lesson, attempting to engage the students' attention and allowing them to begin thinking about the information they should explore in the animation. When completing each lesson in the animation, students are required to answer questions related to knowledge retention and problem-solving transfer to see whether they could retain the newly gained knowledge and apply it to a new situation. Answering the review questions was part of the gamified procedure. Upon answering these questions correctly, a student won rewards and received the honor of having one's name posted at or toward the top of the leader board. This practice of answering review questions aligns with NGSS in promoting students' learning skills by analyzing the content in detail and interpreting the meaning while at the same time applying it to different situations. Furthermore, students' responses to transfer test question items indicate their abilities in regard to conceptual understanding and the flexible use of knowledge (Mayer, 2005b); students were able to track their own correct responses through earning points.

System development. In addition to the content of the socially gamified animation, the other key element related to this instrument is the database design. The database is used to record students' performances when they interacted with content in the system. Due to the limited budgets and technical support, this project selected a free but highly secure database service, Parse APP. The histories of gameplay, including scoring composition, and chat history, which refers to the records of how students interacted with the gamified animation and with other students within the group, were temporarily stored in this web-based server application. Although it is a reliable service for storing students' data of gameplay, it is a third-party service; therefore, a chance of losing and disclosing students' information to others still existed. To resolve this issue, all identifiable information of each student from the database was recoded and was represented by a completely unrelated number or character. The process of de-identification and anonymization is critical in protecting students' privacy. Only the researcher can recognize the relationship between keyed information and students' identifiers. In addition, every time the experiment was completed, the researcher immediately downloaded the saved the data on his computer, and the original data were removed from the server.

The development of software content has afforded greater opportunities in the creation of eLearning applications. Accordingly, this study used a flash-based animation for the control group. Within the gamification and social-gamification experimental groups, in addition to the animation, the researcher added the game elements and social functions to create a socially gamified animation. The Adobe Company has announced that the HTML5 will replace Flash in the near future (Adobe Corporate Communications, 2015); therefore, this study needed to update the technology used and needed to apply the latest software applications to create the game elements and online chat room functions. For this reason, this study selected one of the latest game authoring tools, Unity software, to develop the gaming system (Goldstone, 2009). Another critical reason to implement current technology within eLearning applications is to ensure the quality of the final product and to afford researchers with high-quality technical support (Anderson, 2008).

Multiple software applications were needed within the process of developing the animation and game elements within this research. The visual elements of the animation were developed with Adobe Illustrator and Photoshop, and the structure of the game was completed using Unity software. The items for multiple choices and fill-in-the-blank questions were stored in a Google Spreadsheet and randomly assigned for each stage of the gameplay. The chat room function was created by Photon Unity Networking and implemented to the system (shown in *Figure 6*). The final product of the system was published as a desktop application that is applicable for both Windows and Mac OS operating systems.

Figure 6. A chat room function allows users to communicate with others while playing the game.

Generally, the framework of this instrument consists of Flash animation, a Unity game with with reward structures and online chat room, a Google Spreadsheet as a database, and a web-based server. The animation is embedded on the CReSIS website for users to interact with. After exploring the content in the animation, users logged in to the Unity game to begin the review questions, which were randomly assigned from Google Spreadsheet. The difficulty level of the questions was based on the six learning disciplines of glaciers in the animation, and the questions were randomly assigned to students in gameplay. Students were given the same level of test questions within this range of difficulty. The administrator can decide whether to turn on or off the chat room function while users play the game. Users' reactions over the gameplay and chat histories were stored in the Parse web server (shown in

Figure 7).

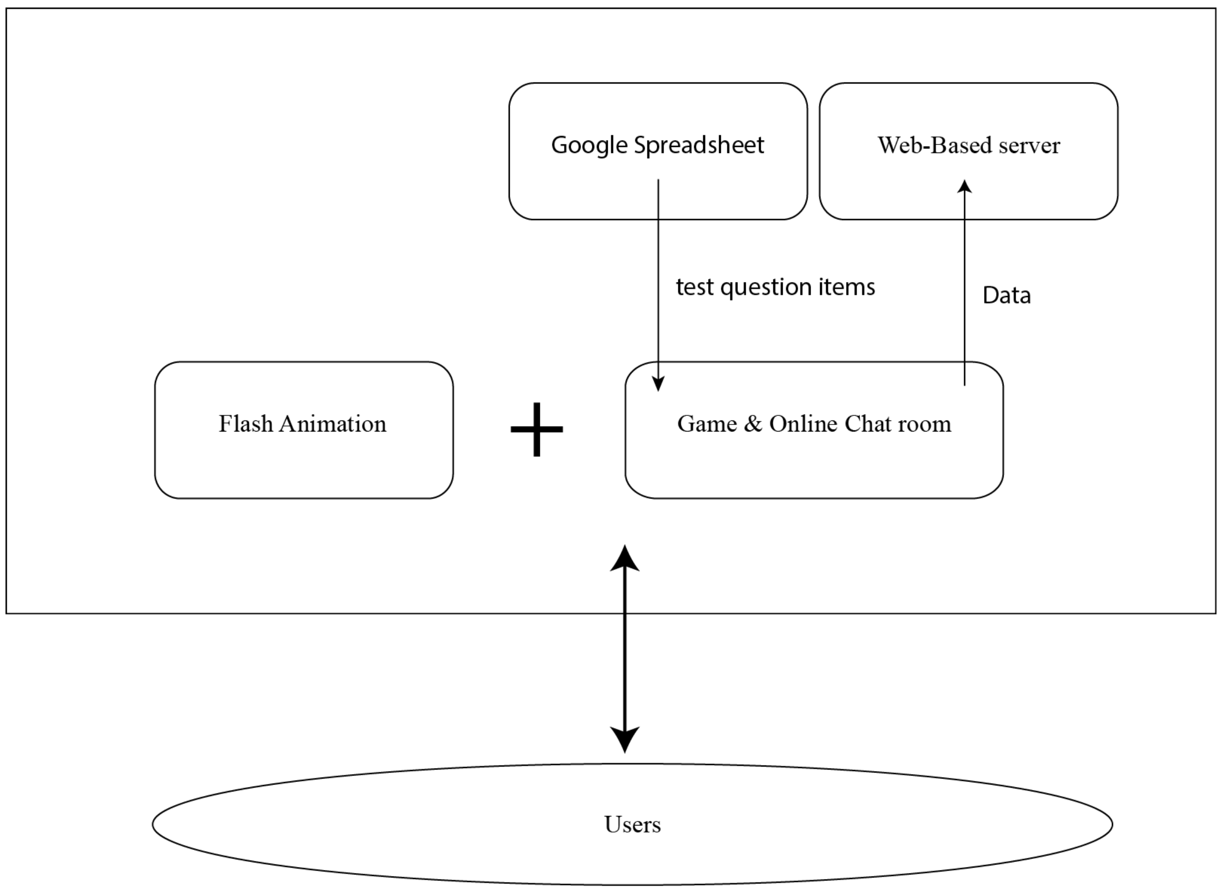

Figure 7. The structure of socially gamified animation.

This development provided a flexible way of implementing game elements into the existing CReSIS animation without recreating a whole new gamified system. In addition, the architecture of the system can run using the modest hardware of PC and Macintosh (Mac) computers. Computers with basic network infrastructures, such as the Internet and web browsers, can run this gamified system. The efficient use of resources facilitates the implementation of the system for testing and data collection.

Experimental Conditions

The experiments were performed in natural environments in which participants are familiar, such as their classroom or computer lab. The primary equipment required in this study was a laptop with basic network functions and an Internet connection. Before starting the test, this researcher requested permission from the KU Human Subjects Committee—Lawrence Campus (HSCL). Participants' rights and privacy were protected in this research. The investigator reviewed the consent form and explained the experiment before the experiment began to avoid future misunderstandings. Participants were told that they could attain the benefits of gaining insight into glacier science through this study and that their responses would guide the design of future social gamification in eLearning applications.

The collected data, including the pre- and post-test scores, emotional responses on the MSLQ survey, and log files, were stored in the primary investigator's office at CReSIS. Only the investigators and the faculty supervisor involved in this study had access to the files. Participants' names were associated by anonymous identifiers in the research findings to help readers understand the context, but their identifiable information was not shared unless (1) it was required by law or university policy or (2) participants provided written permission.

Experimental Procedures

In order to minimize the impact of prior knowledge, the learning topic was not covered in previous classes. In addition, a pretest about the topic was conducted to measure the amount of participants' preexisting knowledge of the content. The experiments were performed in classrooms and computer labs, and the experiment lasted approximately 50 minutes to approximate the length of one class period. During that time, students interacted with five animation-based lesson activities relating to the topic of glaciers, and some of them were asked to use the gamified system to review the content by answering the questions. In addition, all students completed filler tasks to equalize the timeline from learning among all groups

Student participants were randomly assigned to three treatments (shown in Table 3). The first group used nongamified animation and was the control group, while each consequent treatment became progressively more gamified. After the instruction, all students participated in 3 min of filler tasks by discussing what they found face-to-face in order to equalize the timeline from learning activities to post-test among all groups. Students in the second group elaborated on what they learned to compare the effect of social interaction among students within the third group. The results can identify whether the effect of social gamification could lead to improvement related to students' intrinsic motivations, which would in turn enhance their learning performances.

After undergoing the treatments, all groups took a post-test with the same materials used in the pretest to determine the effect of animation, gamification, and social gamification on students' learning performance. The three groups also completed their MSLQ surveys to address the level of their motivation and cognitive engagement across the three instructional methods; the mean scores of these surveys were later analyzed.

Table 3

Research Design

Group	Treatment
Experimental group 2	Socially Gamified Animation (includes animation, game, reward system, and online chat room)
Experimental group 1	Gamified Animation (includes animation, game, and reward system)
Control group	Animation

Research Instrument

This study conducted a pre- and post-test to investigate students' learning performance under the three different treatments. The results of the data analysis verified the effect of gamification and social interaction integrated in a digital animation-based eLearning application, whose purpose was to improve students' science achievements in online settings. The second instrument was the MSLQ, a self-reported questionnaire used to assess students' motivational orientations and their use of different learning strategies for course activities (Pintrich, 1991). This instrument was used to measure participants' motivation and cognitive skills while engaging in learning activities mediated by either gamified or nongamified instructional applications.

Pre- and post-test. A pre- and post-test was used to compare whether the use of social gamification could facilitate students' understanding of the basic concepts of polar science. The gain score from pretest to post-test between the three experimental groups was used to investigate the effectiveness of social gamification with regard to learning performance; in particular, the researcher sought to compare the pre- and post-test scores of the social gamification experimental group with the other two experimental groups representing the other two instructional methods.

The learning content in the animation was designed by Cheri Hamilton, K-12 outreach coordinator at CReSIS; Hamilton also helped designed the pre- and post-test based on the content of the animation. Subsequently, she created a scoring rubric model serving as a standard to assess students' answers. By comparing the scores across three experimental groups, the researcher could evaluate which instructional method has the largest impact on students' understanding of glacier science. The pre- and post-test and scoring rubrics can be found in Appendices B, C, and D.

Motivated Strategies for Learning Questionnaire (MSLQ). The second instrument, the MSLQ, was used to measure students' motivation and cognitive engagement. The MSLQ survey was developed by professors at the University of Michigan and is accessible online at no cost (Pintrich, 1991).

This instrument includes items that assess students' motivation and cognitive strategies used during the learning process (Dewey, 1925; Pintrich, 1991). Statistical and psychometric analyses have shown that MSLQ has a good internal reliability (the Cronbach's alphas for the most individual scales are greater than .70). Furthermore, the subscales of the MSLQ correlate to academic performance, which indicates the predictive validity of this instrument.

Although the MSLQ was initially developed for testing college students, it was later adapted and used with middle school students (Fredricks et al., 2011), who are the target subjects for this research. Because of limited experimental time, this study condensed the MSLQ survey into a 25-item survey. The modified version of the measure, including items and subscales, are presented in Appendix E.

Analysis

The data collected in this study included (1) the scores on the pre- and post-tests of students' learning performance to verify the instructional effect of social gamification, (2) the modified MSLQ questionnaire addressing motivation and cognitive engagement related to learning glacier science content as corresponding to participants within all three levels of gamified animation, and (3) the log files capturing the students' performances on each lesson in the gamified animation. The data were analyzed to verify the use of structural gamification in a multimedia instruction to promote students' emotions and to improve their learning performances in eLearning situations (shown in *Figure 8*).

The following statistical methods were used to analyze this data. The proposed analysis method for the pre- and post-tests of students' understanding of content knowledge is to use two-way analysis of variance (ANOVA) and one-way multivariate ANOVA. With a two-way ANOVA, in addition to the comparison of gain scores across three instructional methods, this statistical method can also verify whether there was a gender effect on participants' scores. Another one-way multivariate ANOVA was conducted to evaluate the effect of the three instructional methods on the retention and transfer tests. The retention test comprises question items that evaluate students' abilities to recall the learning content. The transfer test examines students' abilities to apply learning materials in novel situations. The results of this analysis could assist the researcher in further understanding what kind of learning effects that social gamification can promote: remembering or understanding. Table 4 summarizes the distinction between two kinds of test questions items in this study.

Table 4

Two Types of Test in This Study

Learning Ability	Definition	Test	Question items
Remembering	Ability to recall the learning content	Retention test	Question 1 Question 3 Question 4
Understanding	Ability to apply learning materials in new situations	Transfer test	Question 2 Question 5 Question 6

* The descriptions of the question items is shown in Appendices C and D

Study 2 focused on comparing the different levels of motivation and cognitive engagement between the three instructional methods. To ensure that the modified MSLQ survey could accurately measure students' emotional orientations, this study conducted a confirmatory factor analysis (CFA) in data analysis to adjust this measurement model, which confirms the predicting power of the categories and items in the MSLQ. Next, this measurement model with the variable of instructional methods was used to evaluate whether there was any significant difference related to students' motivation and cognitive engagement across the three different methods of instruction.

The final research analysis examined the relationship between students' emotional reactions to their participation in the eLearning applications and their test scores. To determine whether positive emotion could lead to advanced learning performances, structural equation modeling (SEM) was used to model the measurement of the MSLQ survey and the observed variable of students' post-test scores. If the results of previous studies verified that the different levels of gamification affect students' emotional orientations, this researcher would conduct a follow-up analysis to examine whether the motivation and cognitive engagement among the three instructional groups would result in different learning achievements. In correlating the findings of such a follow-up analyses with students' test scores and MSLQ scores, this study could provide even greater persuasive evidence related to the potential of social gamification in eLearning tool to promote positive emotions that lead to better learning achievement in science education.

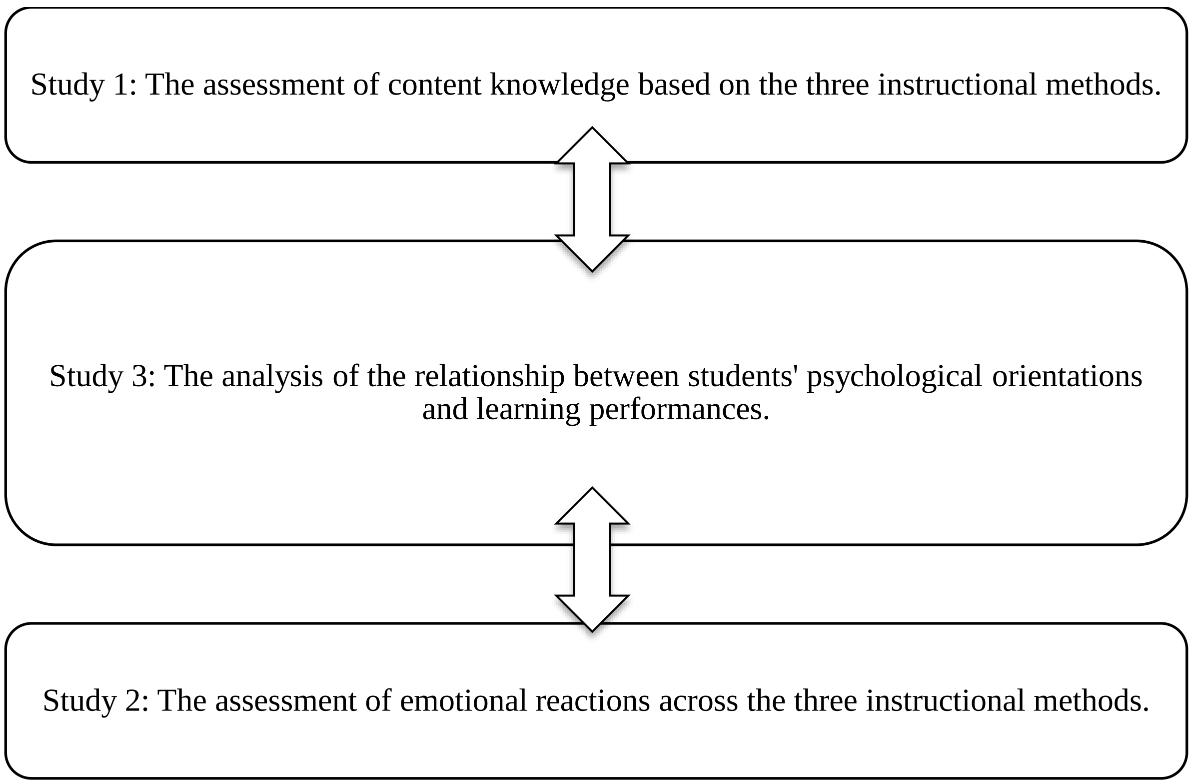

Figure 8. The structure of the three assessment tests.

Quality Assurance

The scores on pre- and post-tests and students' surveys were kept in a locked closet during the analysis process in the researcher's office at CReSIS. The log files of students' accounts, game scores, and conversations in the online chat room were directly downloaded from the server and saved in the researcher's computer after the experiment. The files from the server were decrypted to completely protect student privacy. After all of the collected data was added into the SPSS system (IBM Corp., 2013) or R package, called lavaan (Rosseel, 2012), for data analysis, the original data were kept in the locked closet in the office until the research was completed. When the research was completed and the data were no longer needed, the data were shredded and burned.

Chapter 4: Results

The purpose of the present study was to create evidence to support the use of social gamification. Data-driven educational practices necessitate such research to affirm the perceived need for social gamification in developing multimedia instructions for K-12 polar science in online settings. In order to reach the aforementioned objectives, three studies were undertaken. Study 1 was conducted to examine the instructional effectiveness of social gamification on students' content knowledge. The social gamification was compared with two other types of instructional methods, gamification and nongamified multimedia instruction, to see whether the implementation of this instructional strategy could improve students' understanding of polar science. Study 2 examined students' motivation and cognitive engagement and determined whether there were significant differences between students' psychological statuses when receiving three methods of content delivery. The final analysis considered whether there was any relationship between students' learning performances and their psychological statuses. The findings could assist researchers in clarifying whether the positive emotions such as motivation and cognitive engagement, which students gained during the learning process, could produce better learning outcomes. The subsequent results of these studies could yield recommendations for the implementation of social gamification within potentially useful eLearning technology for science education.

To better describe the three studies and the results, this chapter is presented in three sections. The first section summarizes the methodology of the studies. The second section analyzes each of the studies and applies the results to answer the research questions. The third section ends with the summary of the results across the three studies.

Summary of Methods

This study involved collaborations with after-school programs engaged in partnerships with CReSIS at KU in Lawrence, Kansas. The student samples for the study were fourth to eighth graders. Students took a pretest and then learned the content of polar science through one of three multimedia instructions. After the instruction, they took a post-test and a modified version of MSQL survey to assess how much content knowledge they learned and what their emotional states were while using these instructional tools.

The collected data include students' scores on pre- and post-tests and the MSLQ survey. The data were analyzed in three steps. First, students' pre- and post-test scores were analyzed to determine whether the premise that the eLearning tool integrated with the instructional strategy of social gamification could improve students' learning performance when compared with the original instructional tool and the gamified tool without social function. Second, to answer the research questions related to the emotional effect of social gamification on students' learning experiences, the survey results were used to investigate the differences in students' motivations and cognitive engagement conditions under three conditions corresponding to the use of these three instructional methods. Next, the survey and test scores were analyzed by conducting a SEM to determine whether students' psychological statuses could influence their learning outcomes, which is the premise behind the use of social gamification; this research sought to determine whether social gamification could yield improved learning outcomes. The results of preliminary data analysis for the three studies that answer six research questions are reported in the following sections.

Descriptive Statistical Report

The study invited a total of 112 students to participate and randomly assigned them to one of three instructional methods to learn basic knowledge of glaciers: 34 students experienced the animation to learn glacier science, 40 students learned the same content through the animation and the online game, and 38 students used the animation, the online game, and the online chat room to learn the same content. According to valid data of students' self-identities within the surveys, the distribution of participants in the study was 47 boys and 52 girls (13 sets of missing data) from 8 to 14 years old in Grade 4 to Grade 8. Out of these 112 students, 97 students reported their racial/ethnic backgrounds. The participants in this study were diverse: Whites accounted for 29.9% of the entire group. Other racial/ethnic minority groups, including Black/African American (26.8%), Asian (20.6%), Hispanic (4.1%), Native American/American Indian (5.2%), and other racial/ethnic groups (13.4%), accounted for approximately 70.1% of the entire group. Table 5 presents the racial percentage of distributions of population by gender for each experimental group.

Table 5

Distribution for each gender by race/ethnicity among three instructional methods

Broad Racial/Ethnic Groups	Group1 (%)		Group2 (%)		Group3 (%)	
	Boys	Girls	Boys	Girls	Boys	Girls
White	63.6	23.5	36.8	35.7	6.7	26.3
Black/African American	0	5.9	5.3	0	13.3	0
Asian	0	52.9	31.6	35.7	20.0	15.8

Hispanic	9.1	5.9	10.5	7.1	0	0
Native American/American Indian	27.3	11.8	10.5	21.4	26.7	31.6
Other racial/ethnic groups	0	0	5.3	0	33.3	26.3

Note. Data are from a 100% random sample of students in a Boys and Girl Club, Lawrence, Kansas, and a Chinese school in Kansas City, Missouri.

Regarding the collected data of pre- and post-tests and the survey, 17 students (15.2%) did not complete the post-test, and 25 (21.9%) students did not finish or return the survey. Therefore, the final valid data for the pre- and post-tests were 95 (84.8%) and 89 (78.1%) for the survey. Because the following data analysis required both test scores and survey results, this study only considered 89 sets of data that included both test and survey scores.

Other collated data from the online chat room showed that there were 264 messages. After cleaning the log files, only 48 message contents (18.18%) were related to learning materials of gameplay. Specifically, of these content-related messages, only 23 messages from eight students were asking or answering the questions to win the game. Most of the conversation seems inconsistent and arbitrary. These types of chat histories did not assist the researcher in verifying the exchange of conversation for any particular learning styles mediated by social interactions in an online chat room. Therefore, this study did not include the data of log files in the online chat room for data analysis.

Results of the Data Analyses for Study 1

Descriptive statistics. Study 1 attempts to verify the effect of social gamification in students' learning performances by looking at the changes between students' pre- and post-test scores under three instructional methods: online animation (control group), gamified animation, and socially gamified animation. A total of 89 out of 112 students successfully completed both pre- and post-tests. Within these valid sets of data, the online animation group comprised 30 students (18 females and 12 males), the gamified animation group comprised 29 students (11 females and 18 males), and the socially gamified animation group included 30 students (17 females and 13 males). After receiving the instructions, 89 students had a mean score of 3.98 (SD = 2.76) of improvement from pretest to post-test. Scores of 3.07 (SD = 2.20), 3.69 (SD = 2.83), and 5.17 (SD = 2.85), respectively, represented the improved mean scores of the animation group, the gamification group, and the social gamification group. When considering the gender differences, the means and standard deviations for the three experimental groups of each gender were modified and represented in Table 6. The males' means and standard deviations related to the gamification, and social gamification groups were relatively higher than the girls'. Female students had higher improved scores than males only in the animation group; however, the initial results gave us an indication that there might be differences between instructional methods and learning performances while also considering the gender differences, but we cannot affirm these differences were statistically significant.

Table 6

Means and Standard Deviations for Gain Score from Pre- and Post-Tests

	Girls		Boys	
	M	SD	M	SD
Animation Group	3.44	2.28	2.64	2.06
Gamification Group	5.18	2.99	2.82	2.43
Social Gamification Group	4.76	3.27	5.70	2.21

Note. *M*: mean; *SD*: standard deviation.

According to the first analysis, we realized that on average, both girls' and boys' scores for the post-test were improved across all three instructions. The following analysis was conducted to verify whether these changes were statistically different between three instructional methods. In addition, this study also explored the gender effect on the change of mean scores from pre- and post-test across the three instructional methods. Finally, this study looked at the interaction effect between gender and instructional methods to verify whether the means on change in gain scores among the three instructional methods vary as a function of gender.

The effect of social gamification on boy and girl students' test scores. To answer the previous questions, a 3×2 ANOVA was conducted to evaluate the effects of the three instructional methods and gender on score improvement from the pre- and post-test. Two independent variables occur in this study, gender and the three instructional methods, including the animation (the control group), the gamified animation, and the socially gamified animation. The dependent variable was the score change from the pre- to post-test. The ANOVA indicated no significant interaction between instructional methods and gender, $F(2, 83) = 3.01$, $p = .06$, partial $\eta 2 = .07$, while also no significant main effects for gender, $F(1, 83) = 2.11$, $p = .15$, partial $\eta 2 = .03$; however, a significant main effect for instructional methods occurred, $F(2, 83) = 5.64$, $p < .01$, partial $\eta 2 = .12$. The effect size index, $\eta 2$ indicated that there was a medium strength of relationship between the instructional methods and the gain scores from pretest to post-test. Table 7 summarized the results of the 3×2 ANOVA.

Table 7

The 3×2 ANOVA Results for Gain Score by Instructional Type and Gender

Source of variance	*df*	*F* ratio	η^2	*p*-value
(A) Gender	1	2.11	.03	.15
(B) Instructional methods	2	5.64	.12	.005*
A × B (interaction)	2	3.01	.07	.06
Error	83			

* $P < .05$,

Note. *df*: degrees of freedom.

Because the ANOVA showed significant differences in gain score after receiving the instructions, follow-up analyses to the main effect for these three instructions were conducted to examine which method of multimedia implementation is more effective in students' learning performances. The Tukey HSD procedure was used to control for Type I error across the pairwise comparisons. The results of this analysis indicate that the group under the socially gamified animation improved the post-test score significantly more than either the gamified animation group or the control group without experiencing any gamified strategies in the animation. No significant difference between the control group and the gamified animation group existed, however. Overall, the 3×2 ANOVA indicates the superiority of the instructional method of social gamification in an online animation to improve students' learning performances. Results of the Tukey post-hoc analysis are described in Table 8. The average mean score of social gamification group was 5.17 (*SD* = 2.85). The score was relatively higher than the scores of animation (*M* = 3.14, *SD* = 2.20) and gamification group (*M* =3.75, *SD* = 2.86).

Table 8

Tukey HSD Comparison for Three Instructional Methods

Comparisons	Mean Difference	*SE*	*p*-value	95% CI Lower Bound	95% CI Upper Bound
Animation versus gamified animation	−.612	.67	.36	−1.95	.71
Animation versus socially gamified animation	−2.03	.66	.002*	−3.42	−.78
Gamified animation versus socially gamified animation	−1.42	.67	.03**	−2.81	−.15

* $p < .01$, ** $p < .05$

Note. CI: confidence interval; *SE*: standard error.

The effect of social gamification on advanced learning skills. The next analysis examined the means of the improved post-test scores to verify which types of learning skills increased in the case that students' test scores improved under the conditions of each of the three instructional methods. The design of the question items of the pre- and post-test comprised two categories: retention test and transfer test. The retention test included questions 1, 3, and 4 and were used to test students' recall of content after the instruction. The transfer test comprised questions 2, 5, and 6, which were used to examine the ability to apply what the student learned to related problems. The relationship between these two types of tests and three instructional methods can assist researchers in understanding whether the proposed instructional strategy of social gamification in comparison to other two instructional methods could better promote students' higher level of critical thinking to apply the new gained knowledge to different problems in online learning environments, or whether students' performance under the condition of social gamification was superior to the improvement of students' recall on learning content.

Thus, this analysis involved evaluating the differences of gain scores from pre- and post-test on retention and transfer questions in learning among three instructional methods. In this case, a one-way multivariate analysis of variance (MANOVA) was conducted in order to determine the effect of the three types of instructional strategies (animation, gamified animation, and socially gamified animation) on two dependent variables, the recall and the transfer test scores. The results showed that there were significant differences among the three instructional strategies on dependent measures, Wilks's $\Lambda = .88$, $F(4, 170) = 2.84$, $p < .05$ The multivariate η^2 based on Wilks's Λ was relatively small, .063. This effect size index indicated that 6% of multivariate variance of dependent variables, which are the recall and the transfer test scores, are associated with the instructional methods. Table 9 and Table 10 contain MANOVA results and the descriptive statistics for the means and the standard deviations on the dependent variables for the three instructional groups.

Table 9

Means and Standard Deviations on the Two Dependent Variables for the Three Groups

	Retention		Transfer	
Instructional Methods	*M*	*SD*	*M*	*SD*
Animation	1.97	1.52	1.10	1.30
Gamified animation	1.93	1.80	1.76	1.81
Socially gamified Animation	2.77	1.72	2.40	1.89

Note. M: mean; *SD*: standard deviation.

Table 10

MANOVA Results

Source	Wilks's Λ	*F* Ratio	*df*	η^2	*p*-value
Gain Score	.88	2.84	4	.063	.026*

* $p < .05$

Note. df; degrees of freedom.

The ANOVA on the two dependent variables were conducted as follow-up tests to the MANOVA. Using the Bonferroni method, each ANOVA was examined at the .025 level. The ANOVA on the gain scores of transfer test was significant, $F(2, 86) = 4.48$, $p < .025$, $\eta^2 = .094$, which indicated that the instructional method accounted for 9% of the variance of students' gain score from the pre- and post-test on transfer question items; however, the ANOVA on the retention test group was marginally significant, $F(2, 86) = 2.36$, $p = 1.00$, $\eta^2 = .52$.

Post-hoc analyses to the univariate ANOVA for the scores of transfer questions consisted of conducting pairwise comparison to find which instructional method influenced performance most profoundly. Each pairwise comparison was tested at the .005 divided by 3 or .017 level. The social gamification group produced significantly superior performance on the transfer test questions ($M = 2.40$, $SD = 1.89$) in comparisons with the animation group ($M = 1.10$, $SD = 1.30$); however, the difference between the mean scores of social gamification and gamification groups was nonsignificant. The gamification group and animation group were not significantly different from each other (See Table 11).

Table 11

The 95% Confidence Intervals of Pairwise Differences in Mean Changes in Retention Test and Transfer Test

Retention Test					
				95% CI	
Comparisons	Mean Difference	*SE*	*p*-value	Lower Bound	Upper Bound

Animation versus gamified animation	.04	.43	1.00	−1.17	1.24
Animation versus socially gamified animation	−.80	.42	.21	−1.96	.36
Gamified animation versus socially gamified animation	−.84	.46	.18	−2.11	−.44

Transfer Test

Comparisons	Mean Difference	*SE*	*p*-value	95% CI Lower Bound	95% CI Upper Bound
Animation versus gamified animation	−.66	.41	.41	−1.8	.48
Animation versus socially gamified animation	−1.3	.42	.01*	−2.46	−.14
Gamified animation versus socially gamified animation	−.64	.48	.44	−1.98	−.70

*The difference in means is significant at the .017 significance.

Note. *SE*: standard error; CI: confidence interval.

Discussion for Research Question 1 and Question 2

The first research question attempts to verify the hypothesis that the implementation of social gamification as an instructional strategy could improve the effectiveness of current CReSIS animation in promoting students’ content knowledge of glacier science. The follow-up question further examines whether this effect yields greater benefits on students' higher levels of critical thinking and knowledge construction or on their rote memorization of the content.

Research question 1. This question addressed the differences between male and female students' scores on pre- and post-tests after experiencing lessons involving either animation, gamified animation, or socially gamified animation. A 3×2 ANOVA indicated that gender difference was nonsignificant, but the use of different content delivery methods yields different levels of improvements related to students' test scores. Therefore, this result affirms the hypothesis that the implementation of social gamification in an online animation can improve fourth to eighth graders' content knowledge of glacier science compared with the use of the original animation and the gamified animation without social function.

Research question 2. The second question looked at the instructional effect of three instructional methods (animation, gamification, and social gamification) on retention and transfer tests. This latter test focused on knowledge transfer as a learning principle, which is a major concern in improving the effects of educational practices (Love, 1985). Knowledge transfer is thought to be able to foster students' critical thinking and allows them to be able to integrate learning materials to resolve new problems. Therefore, this study hypothesized that the social gamification based on game-based learning and SDT can better support this learning skill and assist students in applying newly gained knowledge to various situations.

Following the 3×2 ANOVA, the researcher conducted a MANOVA analysis for this question. The results indicated that there was a statistically significant difference between students' scores on transfer tests based on instructional methods. The pairwise comparisons between each group indicated that the social gamification group outperforms the animation group, but other comparisons were nonsignificant. In this case, the current findings partially support the hypothesis that the use of social gamification in comparison to animation can better improve students' high level of cognitive skills in answering questions related to knowledge transfer.

Results of the Data Analyses for Study 2

Descriptive statistics. Study 2 received the data from the modified MSLQ survey from 112 students in fourth, fifth, sixth, seventh, or eighth grade between November 2015 and February 2016. Of the 112 received surveys, 89 (79.5%) were fully completed by fourth to eighth graders. Of these, 23 were not used in the study for the following reason: their surveys were atypical, containing information that appeared to report the data without thinking. If students did not complete either the pretest or post-test, their survey scores were not used.

Interpretation of MSLQ scores. In this study, we modified the original version of the MSLQ survey and selected 25 of the original 44 items as the indicators to measure students' psychological statuses. The modified MSLQ survey with 25 items was used to represent the five criteria in the motivation and cognitive engagement construct (Table 12). According to the manuscript of the original MSLQ survey, the average score of this instrument, as well as the breakdown of the scores for the bottom 25%, middle 50%, and the top 25%, can be used to evaluate students' motivation and cognitive engagement (Pintrich, 1991). When students' scores on MSLQ survey were lower than the average, students could be less engaged or motivated in this course when compared with other students in class, and vice versa.

Table 12

The 25-Item MSLQ Survey

Motivation		Cognitive Engagement	
Criterion	Item Count	Criterion	Item Count
Self-efficacy	5	Cognitive strategy use	5
Intrinsic value	5	Self-regulation	6
Test anxiety	4		

Study 2 addressed differences in motivation and cognitive engagement scores concerning the use of social gamification in multimedia instruction. The first analysis of the data examined the mean score differences of motivation and cognitive engagement scores between three instructional methods. Overall, the results of the descriptive statistics showed that the social gamification group had greater mean scores in motivation (*M* = 5.26, *SD* = 1.18) and cognitive engagement (*M* = 5.42, *SD* = 1.06) than gamification (*M* = 5.02, *SD* = 1.24/*M* = 5.18, *SD* = 1.24) and animation groups (*M* = 5.05, *SD* = 1.21/*M* = 5.31, *SD* = 0.99) did. Table 13 presents the means and standard deviation of motivation and cognitive scores as corresponding to the three instructional methods.

Table 13

Means and Standard Deviations for Motivation and Cognitive Engagement Scores of Each Instructional Method

	Animation		Gamification		Social Gamification	
	M	*SD*	*M*	*SD*	*M*	*SD*
Motivation	5.05	1.21	5.02	1.24	5.26	111
Cognitive engagement	5.31	0.99	5.18	1.24	5.42	1.06

Note. M: mean; *SD*: standard deviation.

The factor validity of the modified MSLQ scales. Before using the collected data from the modified version of the MSLQ survey for follow-up analysis, it is essential to assure that this survey has the same predictive power that the original version has. This 25-item survey should be able to precisely measure the levels to motivation and cognitive engagement while also reducing measurement errors. To ensure this questionnaire is a valid measurement tool, a confirmatory factor analysis (CFA) model was proposed to verify the validity and reliability of the 25 indicators (14 for measuring motivation variables and 11 for measuring cognitive engagement variable) in this modified version of the MSLQ survey.

The lavaan package. There are many software packages designed for CFA, and each software program provides slightly different pieces of information and supports certain types of estimation method, so it is reasonable to include the software application in the report section to better explain the results (Schreiber, Nora, Stage, Barlow, & King, 2006). This study selects the R package, called lavaan, for analyzing latent variable modeling including CFA and SEM. This package is free, but its commercial quality application can support multiple estimation methods such as path analysis, factor analysis, and regression coefficients (Rosseel, 2012).

Model fit assessment. When conducting a CFA, model-data fit is of utmost concern. It can assist researchers in determining the significance of the instrument and can tell how well it fits to the collected data. If the model does not fit the data, parameter estimates may be biased and standard errors (*SE*s) of estimates also could be biased, so the inferences made from the model would be incorrect. Therefore, this study first assessed the model fit with the lavaan package to determine the significance of this two-factor model and ensures that the model adequately fits the collected data.

When conducting a CFA within this research, it was decided that if the construct of the 25-item survey fits the collected data well, these 25 items could best represent and measure two latent variables, motivation and cognitive engagement. Various indices exist that could be used to evaluate whether the proposed measurement model outperforms the saturated model (Hooper, Coughlan, & Mullen, 2008). This study selected the five most widely reported fit indices, model chi-square (χ^2), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) for assessing the model fit. The results of the following fit indices reported that this model did not fit well. The model χ^2 tested the null hypothesis and found that this model fits equally to the saturated model. In other words, this model did not fit better than the saturated model, which aligns with the results of the Chi-Square test of model fit. Another two indices, CFI (0.669) and TLI (0.637) were both smaller than .95, which report that the model did not fit well. In addition, the model of RMSEA (.109 > .05) and the SRMR (0.128 > .08) indicated that the model did not fit well. Due to the misfit model, we cannot use the data of this survey to make any inferences.

Model modification. Because this two-factor model did not fit well the 14 items for motivation variables and 11 items for cognitive engagement variables, the researcher examined the normalized residual covariance matrix to find which items resulted in the misfit. The items with larger significant normalized residual covariance are usually problematic and will cause the misfit, so they should be removed from the model. To improve the model fit, the items with significant normalized residual covariances larger the ±2 were removed. With this standard, eight items were dropped, which were considered as problematic in this model (Table 14).

Table 14

Eight Removed Items with Large Significant Normalized Residual Covariances

Survey Item	Number of Significant Normalized Residual Covariances
2. I am so nervous during a test that I cannot remember facts I have learned.	4
5. Compared with others in this class, I think I am a good student.	2
7. I have an uneasy, upset feeling when I take a test.	7
13. I worry a great deal about tests.	8
14. When I take a test, I think about how poorly I am doing.	4

17. It is hard for me to decide what the main ideas are in the game I just played.	6
18. When work is hard, I either give up or study only the easy parts.	5
23. I find that when playing the animation and glacier games, I think of other things and don't really pay attention to the content.	7

After dropping eight misfitting items with larger residual covariance, the model fit indices indicated that the new construct of the model fitted the sample data well and became capable of measuring students' emotional changes. Table 15 provides an overview of fit indices for the assessment of model fit for the new 17-item survey.

Table 15

The Indices of Goodness of Fit in the CFA Model

N	χ^2 (*df* = 136)	CFI	TLI	RMSEA	SRMR
89	154.052, $p = .014 > .001$	0.929 > .90	0.918 > .90	.059 < .08	.071 < .08

Note. χ^2: model chi-square, CFI: Comparative Fit Index, TLI: Tucker-Lewis Index, RMSEA: root mean square error of approximation, and SRMR: standardized root mean square residual.

This new construct of the survey provided us with a nine-item analysis for motivation and an eight-item analysis for cognitive engagement. The following of these final 17 items included in the survey aligns the objectives of the original MSLQ survey while also retaining its factor validity to measure students' motivation and cognitive engagement (Table 16). Table 17 presented the means and standard deviation of each question item in the final 17-item MSLQ survey. The mean and standard deviation of item08 was relatively higher than the other items for predicting student motivation. Item25 was relatively higher than the other items for predicting student cognitive engagement.

Table 16

The Final 17 Indicators to Measure Students' Motivation and Cognitive Engagement

Motivation	
Self-efficacy	3. I'm certain I can understand the ideas taught in this course.
	6. I can do an excellent job on the problems and tasks assigned for today's class.
	11. Compared with other students, I think I know a great deal about today's subject.
	12. I know that I will be able to learn the material for today's class.
Intrinsic value	1. I prefer class work that is challenging so I can learn new things.
	4. I think I will be able to use what I learn in this class in other classes.

	8. Even when I do poorly on the exit questions, I try to learn from my mistakes.
	9. I think that what I am learning in this class is useful for me to know.
	10. I think that what we are learning in this class is interesting.
	Cognitive Engagement
Cognitive strategy use	15. When I complete the exit questions, I try to put together the information from the animation and from the gameplay.
	19. When I study, I put important ideas into my own words.
	20. I always try to understand what the animation is teaching even if it doesn't make sense.
	21. When I answer the exit questions, I try to remember as many facts as I can.
Self-regulation	16. I ask myself questions to make sure I know the materials I have been studying.
	22. Even when study materials are dull and uninteresting, I keep working until I finish.
	24. When I am playing the animation, I stop once in a while and go over what I have read.
	25. I work hard to get a good grade even when I don't like the classroom activities.

Table 17

Means and Standard Deviations for Student Motivation and Cognitive Engagement Scores

	Motivation	
	M	*SD*
Item01	4.96	1.65
Item03	4.72	1.65
Item04	5.17	1.65
Item06	5.28	1.59
Item08	5.57	1.46
Item09	5.22	1.90
Item10	5.13	1.86
Item11	4.84	1.74
Item12	5.09	1.78
	Cognitive Engagement	
	M	*SD*
Item15	4.75	1.72
Item16	4.84	1.74
Item19	5.09	1.64
Item20	5.40	1.60
Item21	5.66	1.61
Item24	5.18	1.47
Item25	6.02	1.23

Note. *M*: means; *SD*: standard deviation.

Each item had a statistically significant factor loading and the standardized factor loadings ranged from .812 (item22) to .318 (item1). The model path diagram presents the model-based parameters for this CFA model *Figure 9*). In this path diagram, two latent variables, motivation and cognitive engagement, were represented in two circles. The 25 survey items as observed variables are shown as squares. Arrows with one head mean direct effects, and they ranged from .81 to .32. Arrows with two heads represent covariance of the value 0.68 between two latent variables, cognition and motivation.

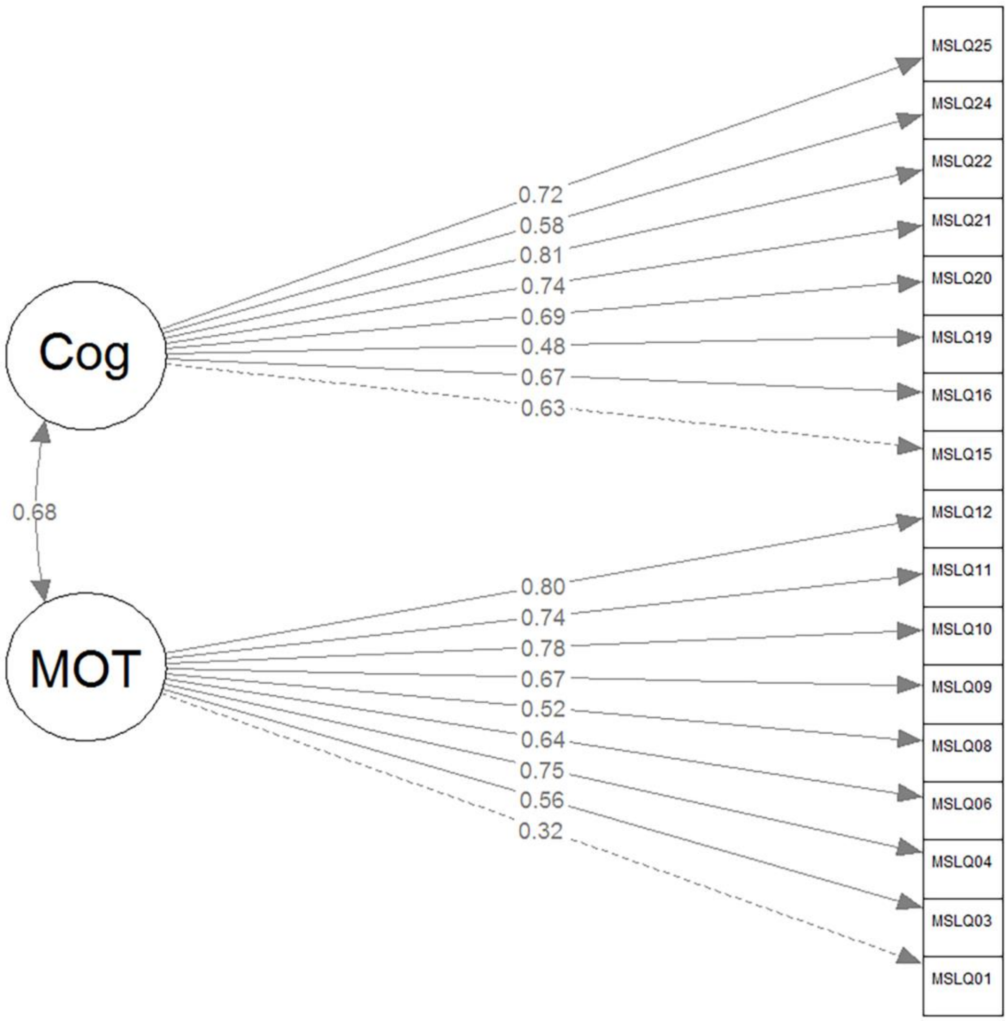

Figure 9. CFA model path diagram.

The differences of MSLQ scores between three instructional groups. The previous section described the building process of the CFA model for the modified MSLQ survey to ensure the validity and the reliability of this instrument in measuring students' motivation and cognitive engagement. The next step was to add instructional variables to this measurement model to examine the relationship between instructional methods and students' emotional responses. Therefore, we built a SEM that allowed us to directly observe the status of the prediction of motivation and cognitive engagement by three different instructional methods.

Dummy coding. Because the instructional method was the categorical variable with three levels (animation, gamification, and social gamification) in this SEM model, an additional recoding step was needed to ensure the results were interpretable. This recoding process is known as dummy coding, which converts nominal variables with three levels to two dichotomous variables (Hardy, 1993). Accordingly, we coded animation and gamification as two dummy variables (0/1) and the level of social gamification was not coded. If the Instructional Group was equal to 1, then Animation would be coded with a 1 and Gamification with a 0. If the Instructional Group was equal to 2, then Animation would be coded with a 0 and Gamification with a 1. If the Instructional Group was equal to 3, then Animation would be coded with a 0 and Gamification with a 0. In this case, the two dummy variables were compared to the social gamification category to see whether social gamification had a larger impact on students' motivation and cognitive engagement in comparison with the instructional method of animation and gamification. The dummy coding is represented in Table 18.

Table 18

Dummy Coding for Instructional Variables with Three Levels

	Group	Animation	Gamification
Animation	1	1	0
Gamification	2	0	1

Social gamification	3	0	0

Path model fit. When the dummy-coded variable was constructed, it was added to the existing measurement model to see whether students' motivation and cognitive engagement factors were predicted by instructional methods. This analysis further examined whether different methods could cause different levels of students' psychological reactions.

The CFA method was conducted to examine the MSLQ survey as a measurement model for motivation and cognitive engagement, so we based it on this CFA model and then created the path model to study further the relationship between the three instructional methods and students' emotions. To verify the predictability of this new path model with latent variables, which is also recognized as the full SEM, it certainly seems desirable to reevaluate the goodness of model fit (McDonald & Ho, 2002). For this purpose, this study assessed the model fit again to study in detail whether the different instructional methods could affect students' emotional changes.

The lavaan package was used to fit the data to the SEM model shown in Figure 10. The Chi-Square test, the RMSEA, the CFI, the TLI, the RMSEA, and the SRMR showed that the current SEM model fitted well (see Table 19 for details). The goodness of fit ensures that the variables of motivation and cognitive engagement represented the same concept between three instructional groups, so bias can be avoided when comparing the effect between three instructional methods on students' emotional responses. Next, parameters were checked in the regression section to examine the relationship between three different instructional methods and students' motivation and cognitive engagement.

Table 19

The Indices of Goodness of Fit in the SEM Model

N	χ^2 (*df* = 147)	CFI	TLI	RMSEA	SRMR
89	193.018, *p* = .006 > .001	0.914 > .90	0.901 > .90	.059 < .08	.07 < .08

Note. χ^2: model chi-square, CFI: Comparative Fit Index, TLI: Tucker-Lewis Index, RMSEA: root mean square error of approximation, and SRMR: standardized root mean square residual.

Comparing the results between instructional groups. The results of regression coefficients between two dummy variables (animation versus social gamification and gamification versus social gamification) and survey scores in motivation and cognitive engagement were nonsignificant (see Table 20). When comparing students' motivation between the social gamification and the animation group, there was a nonsignificant correlation of p = .509 > .05, as was between the social gamification and the gamification group with p = .344 > .05. When comparing students' cognitive engagement between social gamification and the animation group, there was also a nonsignificant correlation of p = .699 > .05, as was between the social gamification and the gamification group with p = .344 > .05. The path diagram in *Figure 10* shows the structure and the parameters in this SEM model.

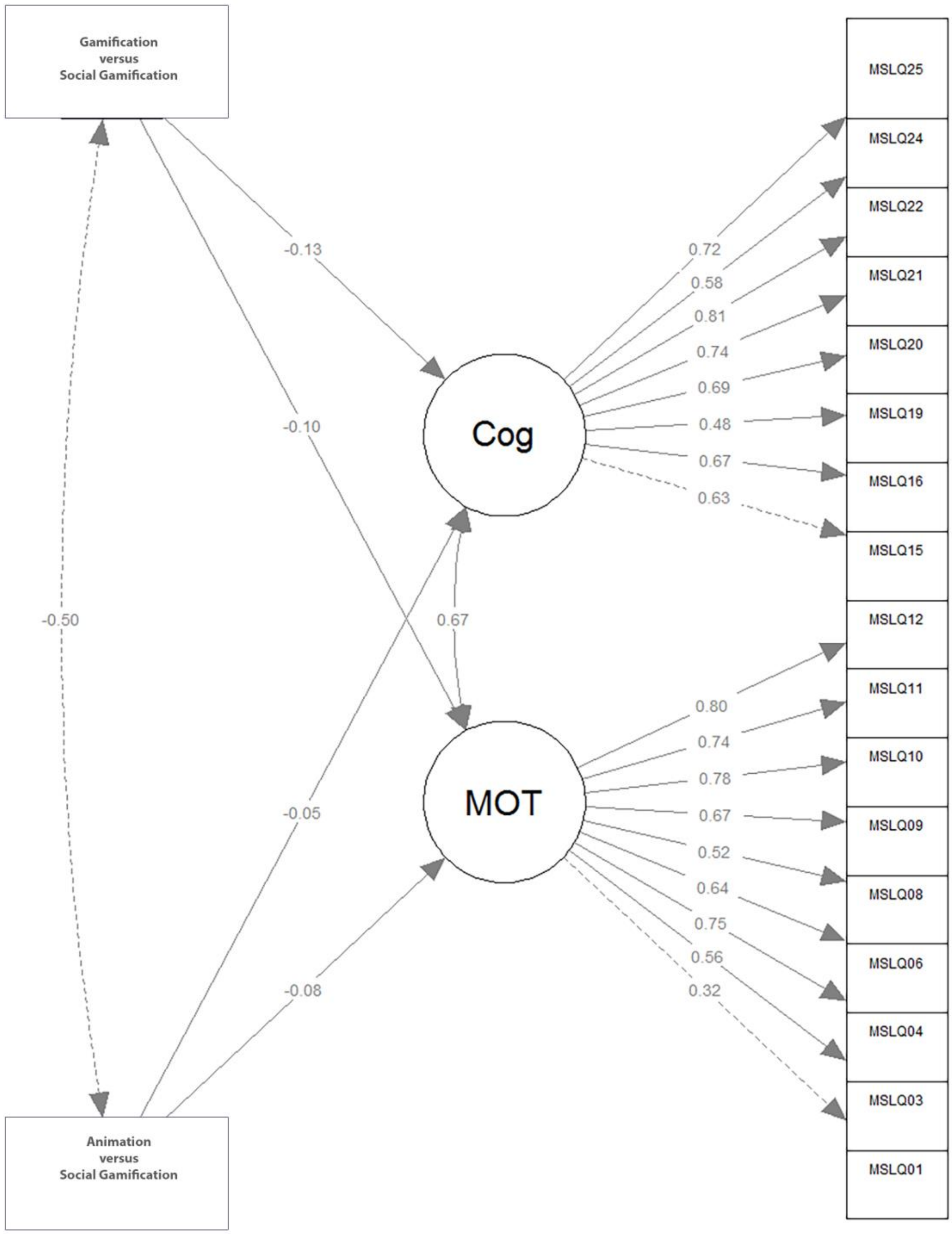

Figure 10. Path diagram of the structural equation modeling (SEM) model for Study 2.

Table 20

The Pairwise Comparisons of Motivation and Cognitive Engagement Based on Instructional Methods

Motivation			
Variables	Std. Coefficient	*SE*	*p*-value
Animation versus social gamification	−0.08	0.144	.52
Gamification versus social gamification	−0.10	.150	.44
Cognitive Engagement			
	Std. Coefficient	*SE*	*p*-value
Animation versus social gamification	−0.05	.285	.70
Gamification versus social gamification	−0.13	.320	.34

Note. *SE*: standard error.

Although the social gamification group was overall higher in both motivation and cognitive engagement scores in comparison to gamification and animation groups, these differences were not statistically significant, so they cannot be trusted.

Discussion for Research Questions 3 and 4

Study 2 attempts to address the psychological effect of social gamification in online learning environments, so it first looked at the accuracy of the modified MSLQ survey to measure students' motivation and cognitive engagement. Next, this study examined students' emotional status based on three instructional methods to verify whether the use of social gamification could better promote students' positive emotions in their learning process.

Research question 3. Research question 3 attempts to determine whether the scores on the modified MSLQ survey could predict students' motivation and cognitive engagement. A CFA ensures the survey as a reliable measurement model by rebuilding the construct with nine items for the latent variable of motivation and with eight items for the latent variable of cognitive engagement. With this new 17-item survey, this study can measure students' emotional changes without errors. In addition, this measurement model can also be used for the follow-up analysis to answer other research questions.

Research question 4. Research question 4 asked the following question: "Are there significant differences between students' motivation and cognitive engagement while controlling for the three instructional methods?" The researcher added an instructional method as an observed variable to the existing CFA measurement model and then created a SEM to determine whether social gamification group had the higher emotional status when compared with animation and gamification groups. The results indicated that the instructional differences were not statistically significant. Therefore, the data analysis did not provide evidence to support the hypothesis that the use of social gamification could enhance higher levels of student motivation and cognitive engagement in online learning environments.

Results of the Data Analyses for Study 3

Study 3 attempted to verify the relationship between students' emotional reactions and learning performances after receiving a multimedia instruction. Because of the nonsignificant results of the SEM analysis in Study 2, it was unclear whether the use of different styles of multimedia instructions could affect the different levels of students' motivation and cognitive engagement. In that case, this study considered three experimental groups as a one-population unit and focused only on the relationship between the population's emotional responses and their post-test scores. This study did not discuss the changes of this relationship based on different instructional methods.

Building structural equation models (SEM). To examine whether students' motivation and/or cognitive engagement could significantly affect their post-test scores after learning the content of polar science through multimedia instructions in a scientific outreach course, another SEM analysis was conducted. The previous study has built a reliable measurement model with a CFA to test students' motivation and cognitive engagement without errors.

Following that measurement model, this study added *post-test score* as an observed variable to develop a SEM model to see whether the scores on the MSLQ survey were useful in predicting students' test scores. In addition, the survey included two latent variables, *motivation* and *cognitive engagement*, so this SEM was a two-factor model with one observed variable. The path diagram seen in *Figure 11* depicts a schematic drawing that represents a concise overview of the SEM model the researcher aims to fit in this study. The observed survey items and post-test scores represented by square boxes and the latent variables (motivation and cognitive engagement) are represented by circles in this path diagram, which illustrates the relationship among these variables.

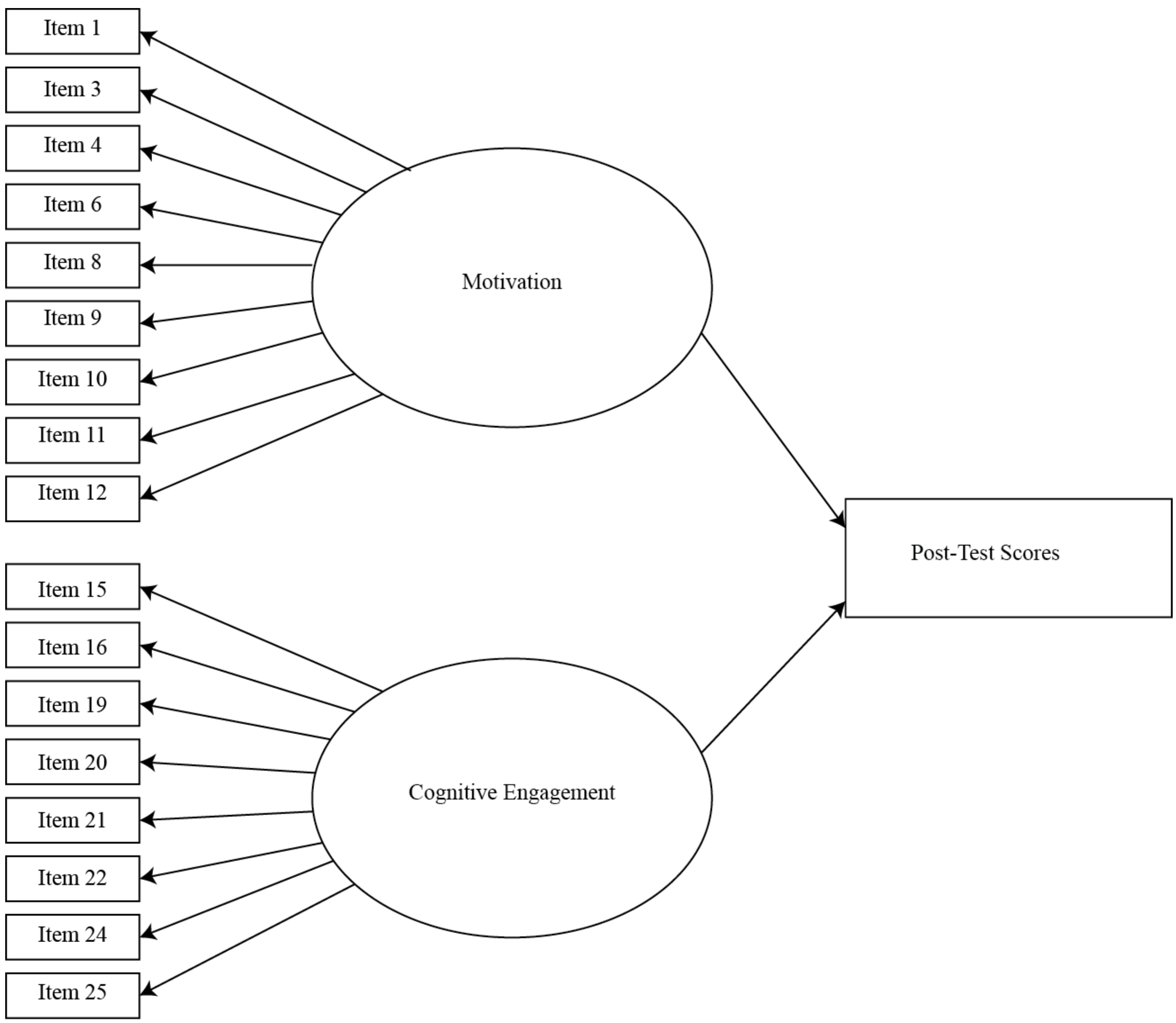

Figure 11. Path diagram of the SEM for Study 3.

Model modification and model fit assessment. After identifying the model, the model fit needs to be assessed to see whether the current SEM model outperformed the saturated model so it can precisely analyze and interpret the results (Kline, 2015). The model fit assessment was conducted with the R package lavaan software application. The initial results did not show the goodness of model fit of this SEM model. The normalized residuals indicted a misfit for the covariance between post-test and item24. As the largest source of misfit came from the covariance between the post-test and item24, we added a direct effect of post-test on item24 to improve the model fit.

Next, the assessment of the fit of the model was reevaluated. The model Chi-Square (χ^2 (153) = 185.247, p = .002 < .05) test indicated the model still did not fit better than the saturated model at a 0.05 threshold, but this statistic can be overly sensitive because of the small sample size in this study. The small samples reduced the power of the Chi-Square statistic, and that may influence the accuracy of discrimination between good fitting models (Hooper et al., 2008; McDonald, & Ho, 2002).

Because of the restrictiveness of the model Chi-Square test for this study, we selected alternative indices to assess the model fit. The CFI (.902) was larger than .90, which reported that the model fit well. In addition, the model of RMSEA (.067 < .08) and the SRMR (.073 < .08) indicated the model fit was acceptable. The following Table 21 demonstrated the fit indices of the SEM model.

Table 21

Goodness of Fit Indicators of SEM model for Study 3

N	χ^2 (*df* = 153)	CFI	TLI	RMSEA	SRMR
89	185.247, p = .002 < .05	0.902 > .90	0.886 < .90	.067 < .08	.073 < .08

Note. χ^2: model chi-square, CFI: Comparative Fit Index, TLI: Tucker-Lewis Index, RMSEA: root mean square error of approximation, and SRMR: standardized root mean square residual.

The final SEM model was a path model, including a measurement model with two latent variables of motivation and cognitive engagement and two observable variables of post-test and item24 (*Figure 12*). With this valid SEM model, we could measure the relationship between students' emotions and learning performances, examining how accurately the survey score predicts students' post-test scores.

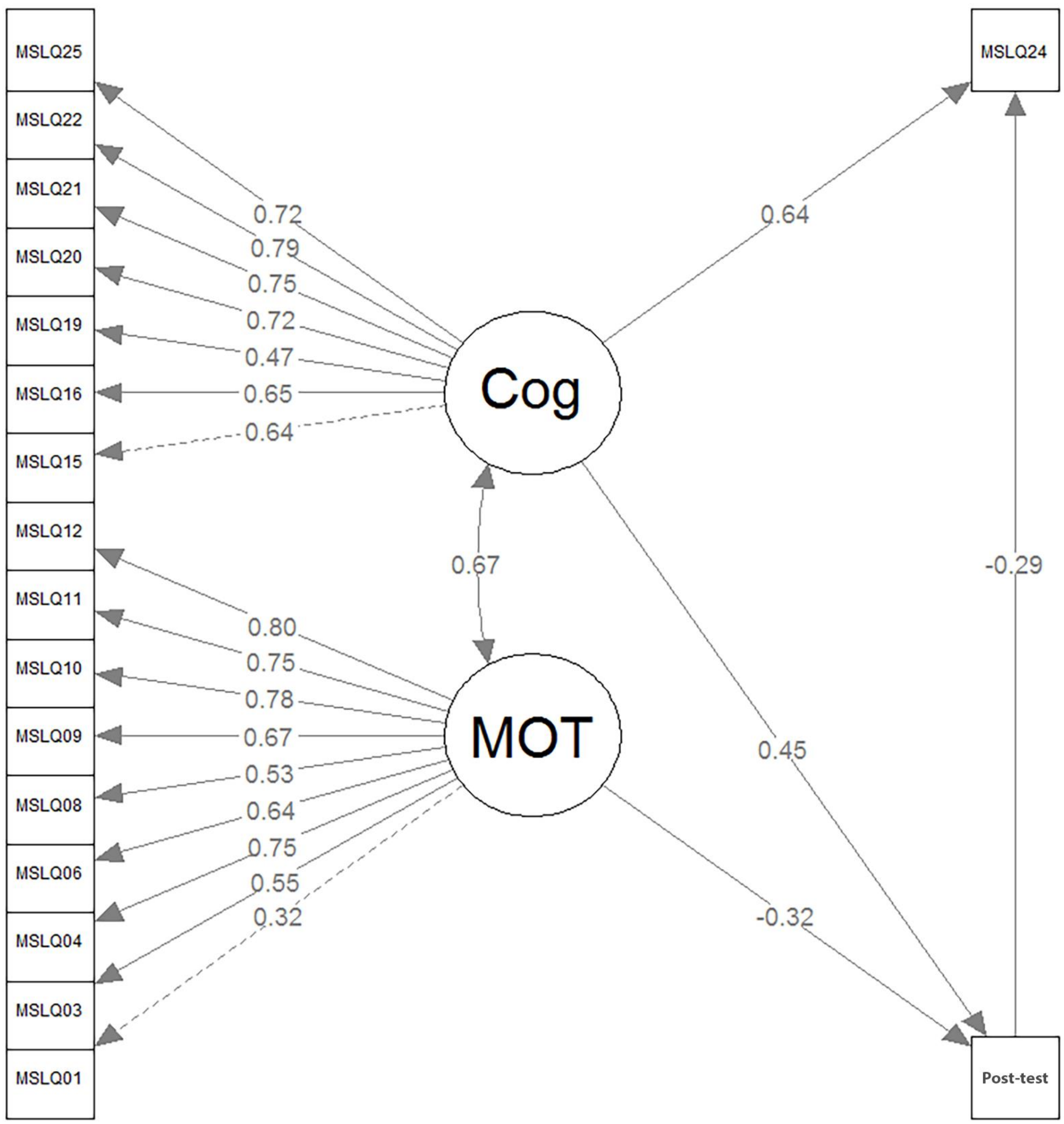

Figure 12. The final path diagram for the SEM model.

Regression coefficients. Next, a linear regression was calculated to predict students' post-test scores based on motivation and cognitive engagement scores from the 17-item MSLQ construct. According to the mode parameter estimate output in the R package lavaan software application (Table 22), the regression coefficient between the post-test and cognitive engagement index was 0.45 (p = .002 < .01). Therefore, this result can be used to infer that post-test scores will be improved by 0.45 SD for every one standard deviation increased in the cognitive engagement score.

The correlation between the post-test and motivation index, however, was nonsignificant (*p* = .102 > .05). The results indicated that there was no correlation between motivation and post-test scores. Therefore, it is unclear whether the scores of motivation could predict students' post-test scores in this study.

Table 22

The Standardized Regression Coefficient

Predictions	Std. Coefficient	*p*-value
Cognitive engagement	0.45	.002**
motivation	−0.32	.102

** *p* < .01

Discussion for Research Questions 5 and 6

Study 3 analyzed the relationship between the results of Study 1 and Study 2. Research question five asked the following question: "Do students' motivation and cognitive engagement predict their learning performances?" Question six asked the following question: "Are there differences about the correlations between students' psychological statuses and learning performances based on instructional methods?" The supplementary analysis of this study attempted to answer these two questions while assisting researchers in determining whether students' emotional changes in social gamification are related to their learning outcomes.

Research question 5. This research question looked at whether the scores on the MSLQ survey can predict students' post-test scores. To answer this question, the researcher built another SEM model, which consisted of the measurement model of the MSLQ survey and the observed variable of post-test scores to study in detail the relationship between students' emotional statuses and their learning performances. The results indicated that the correlation between the post-test and cognitive engagement was significant, but the correlation between the post-test and between motivations was nonsignificant. According to these findings, we can infer that students with higher cognitive engagement will perform at higher level within their learning experiences.

Research question 6. This research question was designed to compare three instructional methods that mediate the relationship between the scores on the MSLQ survey and the post-test. Because of the nonsignificant results of Study 2, the data sets in this research will not generate significant correlations between instructional methods and the scores on both motivation and cognitive engagement in the survey. Therefore, this study cannot provide the answer to this research question. The current study showed only that students' cognitive engagements can predict their post-test scores, but the study cannot determine whether the social gamification group has a stronger predictive power than the other two groups with regard to experiencing higher levels of cognitive engagement. Therefore, it is still unclear whether social gamification can better promotes students' cognitive engagement and whether in turn this cognitive engagement would result in advanced learning performance.

Summary

Chapter four presented three studies that examine the hypothesis of social gamification as an appropriate instructional strategy for multimedia applications to support positive emotions and enhance learning success in online learning environments. When using socially gamified animation, students' understanding of the content knowledge was improved. Significant results relating to students' gained scores on the pre- and post-tests between instructional methods occurred. The improvement from pretest to post-test in the social gamification group was higher than improvements observed within the animation and gamification group; however, when controlling for the gender and test category (whether test items measured abilities related to retention or transfer), no significant differences in their gain scores occurred. Therefore, the current results did not distinguish the gender differences in the instructional effect of social gamification. It is also unclear whether social gamification would improve the higher level of learning skills in regard to applying knowledge to other situations or whether it would enhance only students' memorization of the learning content.

With regard to psychological aspects, no significant differences in students' emotional reactions based on instructional methods occurred. Although the current findings cannot verify whether social gamification could better motivate and engage students in comparison to other instructional methods, students with higher cognitive engagements performed better on their post-test. Chapter 5 will discuss further the interpretations and recommendations of the findings in these studies.

Chapter 5: Discussion

This research project was supported by the CReSIS at KU to improve on existing multimedia instruction to promote the center's scientific outreach programs. According to initial evaluation on the instructional effect of the multimedia instruction, instruction integrated with this interactive animation did not enhance students' content knowledge of polar science in comparison with instructor-led lectures and blended course instruction integrating both animation and teacher-led supplemental course activities. The findings suggested that the animation providing interactions between only content and learners was insufficient for improving student learning; this limiting factor also may have eliminated its instructional effect. The multimedia instruction should encourage learners to interact with the content, the instructor, and each other to ensure success in the learning process (Cook & Dupras, 2004; Strijbos, Martens, & Jochems, 2004). Thus, this study proposed the implementation of social gamification as in instructional strategy to engage and motivate students while using animation to facilitate learning related to basic knowledge of glaciers.

The design and development of the socially gamified animation within this research was guided by SDT, AT, and computer-supported collaborative learning frameworks; these three frameworks focus on the social-contextual conditions that facilitate students' motivations and engage them in the learning process. It was hypothesized that students' learning performances would be improved accordingly. This achievement in science will also prepare more scientists and engineers for the United States in order to retain its global competitiveness (Adkins, 2012).

The purpose of this study was to evaluate whether and how this proposed prototype model could improve students' learning performances. The results identify and verify the instructional effect of social gamification in designing and developing eLearning applications;

subsequently, this instructional effect of social gamification can be judged to be applicable in the presentation of online instruction. For this purpose, the researcher conducted three experimental studies to generate evidence to support the use of social gamification in K-12 science education.

Study 1 focused on the instructional effect of social gamification in facilitating students' content knowledge of polar science. It employed a between-subject design to compare the instructional effect between three levels of gamification: level one, animation without gamification; level two, animation with a reward system; and level three, animation with both a reward system and an online chat room function. Next, gain scores from pretest to post-test were used as dependent variables to see whether there was a significant difference in score changes based on the three levels of gamification. The results provided the evidence to see whether the use of social gamification affirmed the hypothesis in promoting students' learning performances.

Study 2 looked at the psychological status of students during the instruction to see whether there was a significant difference in their motivation and cognitive engagement between the three instructional groups. The major strength of social gamification was to facilitate motivation. Therefore, it is important to verify whether the proposed instructional system related to social gamification will have adequate emotional effect to motivate students and whether it engaged them to actively participate in the learning process. This study used the MSQL survey as a measurement tool to examine the different levels of motivations and cognitive engagements while using socially gamified, gamified, or nongamified instructional tools.

Study 3 attended to the overarching question of whether there is any relationship between students' psychological conditions and their learning achievements. According to the hypothesis, this study assumes that social gamification would enhance intrinsic motivation and regulate learning interests into learning attempts to achieve better learning outcomes. When looking at the social gamification group, students' motivations and cognitive engagements were expected to be positively correlated with their test score. In addition, this effect within the social gamification group was anticipated to be higher than the other two comparison groups, which were the animation and gamification groups.

Summary of the Results

Three studies were analyzed through multiple statistical methods, including ANOVA, post-hoc test, CFA, and SEM. The results for each study will be introduced in the following sections.

The first analysis showed that there was a significant gain in post-test scores across the three experimental groups: the animation, gamification, and social gamification group. The following post-hoc test analysis in ANOVA indicated that the gain scores of the social gamification group were significantly greater than the scores of both the animation and gamification group; however, the difference between animation and gamification was nonsignificant. In addition, this analysis also examined the effect of social gamification and two other multimedia instructions on different genders, but it did not show any significant gender differences.

Another analysis within this study had the purpose of examining the three group students' learning performances on two types of test questions: retention and transfer questions. The results of this analysis were intended to provide researchers further information about whether social gamification could foster advanced thinking and assist students in transferring and applying knowledge into different situations. The results of the data analysis indicated that the social gamification group had statistical significance on transfer test items in comparison to the animation group; however, other pairwise comparisons between social gamification and nonsocial gamification, as well as pairwise comparisons between gamification and animation, were not statistically significant. Moreover, the results of three pairwise comparisons between social gamification, gamification, and animation on students' retention tests were also nonsignificant. This study cannot verify the learning effect of social gamification among the three groups with respect to the two types of test items. Because only one pairwise comparison yielded a significant difference in students' scores on transfer test between the social gamification group and the animation group, this study did not generate enough evidence to support the claim that using social gamification could better facilitate students' learning skills to apply newly gained knowledge to different situations.

The next analysis verified the emotional effect of social gamification in multimedia instruction. A CFA was conducted to modify the survey and to build a measurement model that provides researchers more reliable indicators in the survey to predict students' motivations and cognitive engagements. Subsequently, the researcher added a factor of *instructional method* as a variable to the measurement model to examine its relationship between motivation and cognitive engagement. While the detailed modeling procedure is reported in the Results section, this discussion addresses only the results of data analysis. The change in motivation and cognitive engagement was not dependent on instructional method. With these nonsignificant results, the research did not yield the evidence to support whether the implementation of social gamification could better enhance motivation and engage student in learning process when compared with other instructional methods.

In Study 3, the same measurement model was used to conduct a path analysis with the observed variable of students' post-test scores used to investigate the relationship between students' emotional reactions and their learning outcomes. The data shows that students who had higher cognitive engagement performed higher on their post-tests; however, no statistically significant result between highly motivated students and their leaning performances occurred. In addition, based on Study 2, the instructional method was not a significant factor, so it is not possible to discuss whether the change in the post-test grade following the change in the instructional method was dependent on either motivation or cognitive engagement.

Discussion of the Results

In general, the results of the studies affirmed that social gamification used in multimedia instruction for online instruction helps students learn better the content knowledge in polar science. Their psychological conditions related to cognitive engagement contribute to the better learning performances. The results of this study seem to support the current research on social gamification in multimedia instruction.

A significant difference occurred between social gamification and other instructional methods regarding the improvement in scores from pretest to post-test. This finding supports the idea that learning interests through gamification could compensate for the lack of interaction in the original animation to promote students' learning in online settings. Furthermore, based on the results that the social gamification group had higher gain scores than the gamification group did, the use of online chat rooms can serve as external regulation that can retain student motivation and transfer it within learning attempts. Once students actively participate in the learning process, they will have a higher chance to achieve better learning. In addition, the online chat room in this socially gamified animation reflects the importance of social interactions in developing eLearning tools, which could improve the effectiveness of online education (Harasim, 1996).

The follow-up analysis, however, did not distinguish the effect of social gamification based on different gender. The gender gap is still an ongoing issue in science education (Miyake, Kost-Smith, Finkelstein, Pollock, Cohen, & Ito, 2010), and the analysis of this study tried to see whether the use of social gamification could close this gap. The results, however, indicated that a significant improvement in post-test grades between male and female students did not occur when different levels of gamification were used. Further research is warranted to examine whether the proposed social gamification could have the same instructional effect across gender.

Another advantage of using social gamification regarding its instructional effect in promoting higher level learning skills was partially supported in this study. According to the game-based learning theory, social gamification can promote active learning; therefore, it was expected that students in the social gamification group who have more opportunities to interact with content and therefore to comprehensively construct new knowledge would be able to apply newly gained knowledge to different situations rather than simply remember what they learned. The results supported the previous hypothesis that students who used socially gamified animation produced advanced performances on the transfer test questions in comparison to students within the animation group. Nevertheless, the data did not show that the social gamification group yielded better performances than the gamification group did on transfer test items. Therefore, further relevant research is needed to verify whether social gamification could widely outperform other instructional methods in promoting knowledge transfer skills that the research of game-based learning advocates.

In examining the data of motivation and cognitive engagement from the MSLQ survey, there was no significant correlation between students' emotional responses and instructional methods. The change in students' motivation and cognitive engagement was not dependent on the different levels of gamified animation. This was somewhat surprising given that the results did not align with the literature of gamification research, which posits the potential of gameplay to better motivate and engage people in the learning tasks as well as enjoy the entire process (Hamari, Koivisto, & Sarsa, 2014). Even though students in the social gamification group had slightly higher scores on motivation and cognitive engagement in comparison to students in either the gamification or in the animation group, this result could be biased and misleading. One possible reason that the data did not have significant results could be because the SEM methodology conducted for this study is more sensitive to the sample size. The valid data for this study were only 89, and each experimental group had only about 30 students, which may have resulted in nonsignificant results found in this study.

Given that instructional methods did not have a significant effect on students' motivation and cognitive engagement, the following study controlled instruction and focused on the relationship between students' psychological statuses and learning performances. If the following study could receive a significant result in either motivation or cognitive engagement between students' post-test scores, we at least could approve part of the hypothesis that positive emotions will lead to better science achievement in online settings.

Based on the path analysis with two latent variables, motivation and cognitive engagement, it is evident that cognitive engagement has a positive correlation to the post-test score. In other words, when students have higher cognitive engagements, they will perform better on their post-tests. This finding echoes the research of cognitive engagement that could facilitate higher levels of academic achievement in online settings (Pintrich & De Groot, 1990); however, students' motivations did not predict their post-test scores in this study. Again, the small sample size could reduce the predictive power of the SEM methodology, so future research will need to invite more participants. Another possibility could be the limited experimental time. To match the schedule of the organizations, the study had only 50 minutes for students to complete the pre- and post-test, the instructions, and the survey. Completing so many things within a short period of time could have overloaded young students' cognitive abilities and prevented them from accurately reporting their psychological conditions, which in turn could have skewed the results.

Relationship of results to theory. The theoretical framework for this study was based on SDT and AT to propose the use of social gamification, which emphasizes the importance of social and cultural context in the learning environment to facilitate intrinsic motivation and cognitive engagement. With the increased motivation and cognitive engagement, students will develop self-regulated learning skills in one's own learning process (Zimmerman, 1990). Students with more self-discipline and independence will be more successful in online learning environments (Harasim, 1996; Shea & Bidjerano, 2010; Zimmerman, 1990).

Based on the data analysis for Study 1, it is evident that social gamification can facilitate students' retention and transfer of content knowledge in online settings without face-to-face instruction or assistances. Because this socially gamified system is built on context-driven theories such as social constructivist theory and AT, this finding affirms the importance of social factors in the construction of knowledge. The social interaction is also considered as a critical factor that affects students' successes in online education (Harasim, 1996; Shea & Bidjerano, 2010).

In addition, this result argues that only the enhanced usability of eLearning tools may not be enough to improve learning achievement unless the tools are accompanied with instructional methods that can ensure students' active participations in the learning process. Mayer's cognitive theory in multimedia learning emphasizes design usability to avoid cognitive overload while using the multimedia tools to reserve enough cognitive abilities to focus on learning content and, in turn, to construct mental schemas of knowledge (Mayer, 2005a); however, the CReSIS animation used in this study implemented multimedia design principles to reduce users' cognitive loads. While the animation increased its usability, this user-friendly online instruction did not facilitate students' content knowledge of polar science, so students performed poorly on the test in comparison to students in the social gamification group. Given that lower test scores from the animation group occurred in this study, ease of use alone is insufficient. The implementation of social gamification in the animation can promote learner engagement and active learning to ensure its instructional effect.

Given that positive correlation exists between cognitive engagement and post-test scores, this study in general supports a game-based learning theory in promoting learners' active participation in the learning process (Papastergiou, 2009; Shaffer, Halverson, Squire, & Gee, 2005). The level of cognitive engagement of the students was a significant factor in their post-test grades, so it is reasonable to review the items of the MSLQ survey to verify which factor supports students' cognitive engagement. In examining the eight items in the survey, the better use of cognitive strategies, such as rehearsal and elaboration on the content, appears to lead to better learning outcomes. These cognitive skills reflect the outcomes of active learning in the construction of knowledge (Meyers & Jones, 1993).

Furthermore, self-regulation and effort regulation were also found in the survey to promote students' cognitive engagement. This finding shows, to a certain extent, that the multimedia system used in this study promoted self-regulated learning, which is related to enhanced intrinsic motivation (Ryan & Deci, 2000a); however, this study was not able to distinguish whether this psychological effect came only or mostly from social gamification. These initial results of the data analysis did not provide enough evidence to support the claim that social interactions based on SDT could be used to assist learners in the process of transferring motivation into learning attempts, which, in turn, would lead to better learning performances. This unsubstantiated concept, however, may result from certain limitations of this study, such as limited sample size and short experimental time. Thus, further research is needed to clarify the emotional effect of social gamification on students' learning performances.

Implications for Future Research

For Study 1, the independent variable was the method of instructional delivery, and three levels of gamification were used in multimedia instruction. The data from this study generally support the idea that social gamification used in CReSIS's outreach programs was beneficial to students, regardless of gender, age, or ethnicity. It further supports the idea that the use of social gamification in developing the eLearning tool facilitates learning better by creating engaging learning experiences. Overall, this finding affirms the hypothesis that the use of social gamification can improve the instructional effect of multimedia instruction to motivate and improve students' learning of glacier science.

The findings of this research also suggest that the development of multimedia instruction should focus on how to promote learner engagement and active learning rather than simply facilitating knowledge dissemination. The previous examples of applied technology to disseminate learning content such educational programs on radio and TV did not reach their educational objectives in promoting content knowledge but discourage people from learning through such technology-enhanced applications (Fabos, 2004). Therefore, future studies would focus on the implementation of social gamification to create engaging learning environments and to track its effectiveness.

With regard to assessment, since the concept of gamification originated from game-based learning, it is necessary to identify and verify particular pedagogical affordances of social gamification with specific reference to DGBL theory, evaluating whether, or to what extent, the use of social gamification could promote active learning, inquiry-based learning, collaborative learning, or other learning styles that game-based learning proposed. In addition, research on the effectiveness of social gamification for online instruction also needs to be conducted to measure which types of learning skills that social gamification could foster. In reviewing these learning skills such problem-solving, knowledge transfer, self-efficacy, effort regulation, etc., researchers can further realize which part of learning theories related to game-based learning that social gamification could better support.

Limitations. The primary limitation of this research is its sample size. Because the education team at CReSIS at KU is not a large organization, it works only with schools in Lawrence and Topeka, Kansas, and the greater Kansas City area; furthermore, not all of the schools in these areas were willing to participate in this study. Another obstacle related to the participants in this study is the application process. When conducting research in K-12 education, a substantial amount of paperwork is required for review to protect young people's safety and privacy over the experimental process, and this tedious and lengthy process may reduce schools' and teachers' willingness to join the study. As a result, this research was able to recruit only 112 participants from after-school programs in Lawrence and Kansas City, Kansas. After data cleaning, this study used only 89 valid data sets; this small sample size may have reduced the chance of discovering significant results.

For example, the small sample size reduced the power of the data analysis for the second and third studies. In these two studies, the use of SEM analysis is more sensitive than the other statistical methods to the sample size so a small sample size increases the chances of nonsignificant results (Hooper, Coughlan, & Mullen, 2008).

In addition to the small sample size, the selection of participants in this study could have increased the risk of sampling bias. The student sample from the same geographical area may not be accurate or represent the group of students between fourth and eight grades in the United States. To better examine the data to answer the research questions, future studies need to recruit more student participants from diverse backgrounds.

Another limitation to this study was the experimental time. The CReSIS education team provides outreach services for the schools on an irregular basis, so it is challenging for this study to establish regular instructional sessions. In addition, the experimental time had to follow the organization's schedules. Because of these restrictions, the research design could not involve the participants when running the experiments over long periods of time. This study allowed only for 50 minutes for students to complete all of the tasks, including the pre- and post-test, the multimedia instruction, and the survey. With that short period of time to complete these multiple tasks, young students may have been a bit exhausted and may have had difficulty concentrating on answering the questions for both post-test and surveys, which were the last two tasks students needed to complete. Therefore, future studies need to consider ways to reduce information overload by either extending the experimental time or splitting the experiments into small segments over the course of different days. By avoiding such an extraneous cognitive overload, a future study could get more reliable data from the participants.

While conducting the data analysis, this research used two different software applications: IBM's SPSS Statistics for Study 1 and the R package lavaan for Study 2 and Study 3. Data analysis on R package lavaan reveals that the type of information used in the interpretation of regression correlation for SEM analysis may not be effective because the software may have limitations (Rosseel, 2012). For example, the package provides limited functions to control and demonstrate the path diagram for showing the detailed information and the entire structure of the path model. To address these issues, other commercial packages such as Mplus, SAS, or EQS may be considered for future studies.

Next, the initial research design between gamification and social gamification was intended to verify the importance of social factors in developing multimedia instruction; however, based on the data analysis for this study, the comparison between gamification and social gamification was not significantly different in the mean scores on the pre- and post-test and MSLQ survey. A number of possible reasons exist as to why this discrepancy occurred. The first, and perhaps most likely, reason is the sample size. Besides increasing the sample size, which would enhance the accuracy of verifying the effect of social gamification across different instructional methods, subsequent research also needs to examine the kind of conversations within the online chat room to fully understand the impact of social and cultural factors in virtual learning environments on students' learning performance. Students' conversations during the learning process often provide insights with respect to social interactions that contribute to the collaboration in an online learning environment. Thus, the number of messages sent and replied can be used as a quantitative indicator that can suggest which students are more active and collaborative learners. Along with the studies on the frequency and amount of online chat room use, qualitative studies also need to be conducted on student and teacher conversations to find the patterns related to their learning attempts.

According to research of collaborative online learning, students' online messages can be classified into four categories: social, procedural, expository, and cognitive (Oliver, Omari, & Herrington, 1998; Santos et al., 2003). The social and procedural conversations are not directly linked to collaborative learning. On the other hand, in expository and cognitive conversations, students exchange knowledge and discuss matters to better understand the content, which demonstrates a higher level of social interaction in collaborative learning (Santos et al., 2003). Therefore, more expository and cognitive conversations among students correlate to the effectiveness of gamification in the promotion of social interactions in an online learning environment.

In sum, the initial results of the study indicated that there was a high instructional effect of social gamification across the other two instructional methods in promoting students' content knowledge of polar science; however, limitations in research design prevent this study from answering all the research questions. For example, it is still unclear whether social gamification could better promote engaging learning experiences that facilitate students' learning performances. In addition, the effect of social interaction was not examined in detail in this study to emphasize how social context in learning environments could improve academic achievements in online settings. Thus, further studies will be needed to unveil the effect of social interactions and emotion in social gamification to better support eLearning in science education.

Implications for Practices

The study must be conducted in normal K-12 classroom settings to reevaluate and to improve the quality of the results. The goal of the project was to apply social gamification in multimedia instructions to widely support the outreach programs at the CReSIS at KU and to promote polar science at the K-12 level. The final product also can be used for teachers as a supplemental tool to facilitate their science teaching. The data in this study showed that the socially gamified animation was beneficial to students' understanding of content knowledge of glaciers. The instruction involving socially gamified animation was demonstrated to help students in after-school programs to learn polar science through using this multimedia instruction; however, since the settings in schools and after-school programs are different, the findings from this study may not be applicable to the science in school. Thus, it is necessary to conduct another study in school settings to assess the effect of social gamification in promoting regular science curriculum.

Another implication of this practice in social gamification is to assist educators with addressing technological trends in education. As the International Society for Technology in Education (ISTE) suggests within its evaluation of current course developments, technology needs to be part of the discussion for improvement to meet the needs of a new generation of students (International Society for Technology in Education, 2002). Teachers are expected to promote and model digital-age work and learning in their curricula. This study provides an example of an eLearning tool that can promote engaging learning experiences for students to learn science.

Although this study demonstrates a practical way of using socially gamified animation to engage students in the learning process, which in turn can improve their learning outcomes, the applied technology for social gamification may need to change to meet current schools' standards. Every school district has its own policy for using technology. The current system developed by Adobe Flash and Unity software may not be easily obtainable in current school settings because these two software applications are not supported in schools in Kansas. While this socially gamified application could be improved and implemented into school settings, it is necessary to consult with school districts and work with their IT departments to adopt the technology for which schools can provide support services.

If the practice of social gamification has been shown to be beneficial for students in learning schools' science courses, there will be an increasing need and/or demand for more collaboration between CReSIS's outreach programs and schools. For example, if socially gamified applications are going to be incorporated into classes, schools and CReSIS must provide training and ongoing support for teachers who choose to use the systems in their curricula. While students with increased motivation in these scientific topics are willing to learn more, teachers must take into consideration providing advanced learning content to best serve these students. The education team at CReSIS would then provide technical support to incorporate the content into the systems. With this coordinated co-construction of course technology in social gamification, this project eventually will reach its objectives of providing high-quality services in science education and preparing more professionals in STEM fields.

Another goal of this project is to promote either online or hybrid learning in K-12 education. Showing teachers high-quality eLearning tools will eliminate teachers' concerns about the effect of using technology in their courses. Using such tools that have been proven to be effective also can ensure the quality of the online or blended course (Puzziferro & Shelton, 2014). Given that CReSIS will prepare the tools and provide the service for teachers, it may increase teachers' willingness to integrate this eLearning tool into their curricula. Because the ISTE's National Educational Technology Standards for Teachers (NETS-T) requires new-generation teachers to design and develop digital-age learning experiences and assessments for their students (International Society for Technology in Education, 2002), this project will provide the support for teachers to apply their course materials into online settings. The significance of such a practice will benefit K-12 education in addressing technological trends and will provide better services for students.

Summative Conclusion

The significance of this study relates to the application of social gamification in multimedia instruction that promotes high-quality online instruction while creating an engaging digital learning environment for K-12 science education. For this study, the variable was the three levels of gamification in an interactive animation: social gamification, gamification, and nongamification on multimedia instruction. The data from this study generally support the idea that the use of social gamification in the animation promotes students content knowledge of glaciers. It further supports the idea that the increased cognitive engagement through using technology in learning polar science facilitates learning; however, this emotional effect was not proven to be derived only from social gamification. Thus, the causal relationship between emotional effect of social gamification and students' advanced learning outcome was not verified in this study. More studies focusing on social gamification are required; these future studies could be applied to practices that support students' psychological needs so they can succeed in science education.

While advances in social gamification have the potential to contribute to students' mental needs and academic achievement, the practices related to this instructional strategy should be reevaluated in regular school settings. The results could provide both schools and teachers with evidence that the appropriate design of eLearning tools, built according to not only theory but also related research, will foster students' learning performances. At the same time, these appropriately designed eLearning tools will also serve as a supplemental tool for teachers to model a digital-age learning environment. Further research needs to be conducted in cooperation with schools and teachers to create engaging digital-learning contents that use multimedia and social gamification. With this concerted effort, these subsequent research projects would maximize the quality of online instruction for future generations of learners.

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APPENDIX

APPENDIX A

Question items in the Social Gamified System

Multiple Choice Questions					
Questions	Option 1	Option 2	Option 3	Option 4	Answer
What is the difference between ice sheets and ice shelves?	ice sheets are on land, ice shelves are over water	ice sheets and ice shelves are both over water	ice sheets are over water, ice shelves are on land	ice sheets and ice shelves are both on land	1
Where do glaciers form?	where the land is rocky	where snow doesn't melt	at the equator	on the earth's oceans	2
How long does it take snow to turn into firn in Glacier Fun?	9 years	9 months	9 days	9 hours	1
What causes the ice crystals	human activity on the snow	ice crystals melt into firn	the weight of the snow	summer weather changes the crystals to firn	3

to change into firn?			changes the crystals		
The cracks form on the top of ice because ... ?	the layers are brittle and move at the same speed	the layers are solid and move at different speeds	the layers are solid and move at the same speed	the layers are brittle and move at different speeds	4
How do the seasons affect the ice?	they don't affect the ice	there’s more ice in the winter than summer	there’s more ice in the summer than winter	there’s less ice in the winter than summer	2
What is the line called where the ice is not receding or growing?	fall line	physics line	skyline	equilibrium line	4
What are the rocks and sand	till	crevasses	firn	moulin	1

left behind by a glacier called?					
How do glaciers change sea level?	they fall and don't melt	they pick up rocks and dirt	they add water to the ocean	they move across the land and surface	3
What happens to glaciers when the slope is steeper?	the glacier moves faster	the glacier melts away	the glacier moves slower	no change	1
What happens when glaciers are thicker or have more snowfall?	the glacier melts away	the glacier moves slower	the glacier move faster	No change	3

What is a moulin?	A glacier that forms within a cirque basin	a tunnel or hole that melted ice water runs down	the top layer of a glacier	a process that change crystal's shape	2
Which of these doesn’t a glacier create?	swamp	rivers	valleys	lakes	1
What do glaciers do to the sea level?	cause it to rise	cause it to fall	cause it to decline	no change	1
How long may it take snow to change into glacial ice?	100 years	1 year	10 years	1000 years	1
What does not make a glacier move?	wind	moulins	ice thickness	slope	1

Where does the ice slow down the most?	at the end (terminus)	at the top (surface)	at the front (face)	where the glacier comes from (source)	1
How much of the earth is ice?	5%	20%	1%	10%	4
Which of these landforms does not come from a glacier breaking?	till	pond	moraine	U shaped valley	3

Fill-in the Blank Questions

Questions	Answer
What makes a glacier move?	ice thickness/thickness/slope/water/moulin
If the top of the ice is called the surface, what is the bottom called?	the base

The end of the glacier is the _____	terminus
How have the glaciers changed from 15,000 years ago?	Most are gone and melted / disappear / recede
The beginning of a glacier starts at the _______	source
The cracks that form in glaciers are called _________	Crevasses
How do glaciers pick up rocks and dirt? by melting and ______	refreezing/freezing
When piles of till build up, it is called a _______	moraine
Scientists watch glaciers accumulate and ________________	recede/get smaller/disappear
Do moulins make glaciers move faster or slower?	faster

In a valley glacier, where would you find the most crevasses?	at the end/terminus

APPENDIX B-1

Approved Institutional Review Board (IRB) from the University of Kansas

THE UNIVERSITY OF KANSAS
Research

APPROVAL OF PROTOCOL

November 19, 2015

Kuangchen Hsu
kchsu@ku.edu

Dear Kuangchen Hsu:

On 11/19/2015, the IRB reviewed the following submission:

Type of Review:	Modification
Title of Study:	Gamification in Web-based Computer Animation: Implementing Game Mechanics for Increased Motivation and Collaborative Learning in Glacier Science
Investigator:	Kuangchen Hsu
IRB ID:	STUDY00000912
Funding:	Name: National Science Foundation, Grant Office ID: ANT-0424589
Grant ID:	None
Documents Reviewed:	• assent procedure for 4th grader, • Parent-Guardian Consent, • HSCL_Initial_Submission_Form_kuang.pdf, • rec flyer_KCHSU.pdf

The IRB approved the study on 11/19/2015.

1. Notify HSCL about any new investigators not named in the original application. Note that new investigators must take the online tutorial at https://rgs.drupal.ku.edu/human_subjects_compliance_training.
2. Any injury to a subject because of the research procedure must be reported immediately.
3. When signed consent documents are required, the primary investigator must retain the signed consent documents for at least three years past completion of the research activity.

Continuing review is not required for this project, however you are required to report any significant changes to the protocol prior to altering the project.

Please note university data security and handling requirements for your project:
https://documents.ku.edu/policies/IT/DataClassificationandHandlingProceduresGuide.htm

You must use the final, watermarked version of the consent form, available under the "Documents" tab in eCompliance.

Sincerely,

Stephanie Dyson Elms, MPA
IRB Administrator, KU Lawrence Campus

Human Subjects Committee Lawrence
Youngberg Hall | 2385 Irving Hill Road | Lawrence, KS 66045-7568 | (785) 864-7429 | www.research.ku.edu

APPENDIX B-2

Approved Institutional Review Board (IRB) from Lawrence Public Schools

Lawrence Public Schools
110 McDonald Drive
Lawrence, Kansas 66044-1063
Telephone: (785) 832-5000

November 9, 2015

Kuang-Chen Hsu
2357 Surrey Drive
Lawrence, KS 66046

Re: RS4867, IRB STUDY00000912

Dear Kuang-Chen,

Your application to conduct research in the Lawrence Public Schools has been reviewed and approved.

Final approval rests with the building principal. A copy of this letter of approval and a thorough explanation must be provided to each building principal at the time you request to work with the district's students and/or staff. Each principal must sign the enclosed Principal's Consent Form and this signed document must be on file in this office prior to initiating your study.

While we recognize the importance of your research, it may not interfere with the district's educational program. At all times during your project, researchers and subjects must be in view of school district staff. All costs associated with this research are the responsibility of the researcher. Any changes in your project must have approval from this office prior to implementing the changes.

Please note that your research project has been assigned Lawrence Public Schools research number RS4867. Your permission to conduct research in the District expires one year from the date of this notice. If your project is to extend beyond this date, you will need to reapply for authorized permission prior to the expiration date and obtain the requisite principal signature(s). Failure to reapply will result in the inability of the principal investigator to conduct further research in the Lawrence Public Schools. Until such time as a new application to conduct research is approved by the district's Institutional Review Board, no research may be conducted. Thank you for your cooperation with our district policies and procedures.

We request that you submit an abstract of your findings as soon as they are available for possible dissemination among interested educators. We appreciate your interest in Lawrence Public Schools and hope that meaningful data is gained from your efforts.

Sincerely,

Terry McEwen, Ph.D.
Director, Curriculum, Instruction and Assessment

Enc: Principal's Consent Form

CC: IRB
Angelique Nedved, Ed.D., Assistant Superintendent, Teaching & Learning

APPENDIX B-3

Recruiting Flyer 01

CReSIS
Center for Remote Sensing of Ice Sheets

VOLUNTEER STUDENTS NEEDED!

Provide your real-time feedback to the Glacier in Motion multimedia instruction system and help improve science learning by signing up to participate in the study now!

PURPOSE!

We are currently seeking **4th - 8th grade** students to participate in a study investigating the effectiveness of a newly devel-oped game-like multimedia application to teach students to learn basics of glaciology.

ELIGIBILITY!

School students **from the grade 4 to 8**, ages 9-14

WHAT IS INVOLVED? ??

As a participant in this study:
1. You will be asked to take a 10 - minute pretest at the beginning of the experiment.

2. You will be randomly assigned to either use or not use the Glacier in Motion multimedia application before arriving for the study. Those who will use the application need to make an account with your name, email address **(optional)**, and school information to sign up with the system.

3. You will take a 10 - minute posttest and a survey related to your learning experience after completing the lesson.

WHAT DO YOU GET? ??

You will have benefits of gaining insight into glacier science through the self-reflection component of this study.

We appreciate your consideration. Your participation in this study will help researchers and instructors learn how to improve and develop an effective multimedia application to make science learning more interesting and engaging.

If you are interested in participating or would like more information, please feel free to Contact Kuang-Chen (Kuang) Hsu [kchsu@ku.edu]; 785-864-7842; 343B Nichols Hall, Lawrence KS

APPENDIX B-4

Recruiting Flyer 02

Disciplinary Core Ideas:

4-5: ESS1.C; ESS2A; ESS2.C; PS3.C; PS1.A; PS2.A; PS2.B
6-8: ESS1.C; ESS2A; ESS2.C; PS3.C; PS1.A; PS2.A

Directions

For experimental groups

1. The teacher will read and explain the consent form for students.
2. Students will take a 10-minutes pre-test to examine their fundamental knowledge of a glacier.
3. Students are given the link to the Glacier in Motion animation: https://cresis.ku.edu/content/education/k-12/games/glacier-fun. Students will explore learning content in the animation for 10 minutes.

4. The teacher will copy the Game folder to desktop, double clicking the PUN.exe to launch the application (For Mac users, double clicking the PUN_MAC.app)
5. Next, the teacher will help student create an account with an ID number, email address, and school information to sign up with the system (In order to protect respondent confidentiality, ID number and email will not reveal any of student's personal information.)

6. After students log in, clicking on the Game button on the main page to start playing the game for 10 minutes.

7. Within the game, students will win points, advance levels, and earn badges by answering 2 types of questions: multiple choices and fill in the blank questions.

8. If students do not know the answers, they can click on the "?" button and view hints.
9. During the gameplay, some students are allowed to chat with other students in the chat room in order to verify if social interactions among peers could improve their engagement and learning performances.
10. After completing the lesson, students will ask to take a 10-minute post-test and a survey to share their learning experiences with the researcher.
11. The gathered scores in the game and the pre-and post-test will not affect students' course of evaluations, or assessments at school.

For Control Groups

1. The teacher will read and explain the consent form for students.
2. Students will take a 10-minutes pre-test to examine their fundamental knowledge of glacier
3. Students are given the link to the Glacier in Motion animation: https://cresis.ku.edu/content/education/k-12/games/glacier-fun.
Students will explore learning content in the animation for 10 minutes.

4. After completing the lesson, students will be asked to take a 10-minute post-test and a survey to share their learning experiences with the researcher.
5. The gathered scores in the game and the pre-and post-test will not affect students' course evaluations, or assessments in school.

Assessment

Pre - and Post - Test:

CReSIS outreach coordinator Mrs. Hamilton's pre- and post-test will be conducted to evaluate whether this learning activity can improve student's content knowledge.

MSLQ survey:

25 survey questions derived from the middle school version of Motivated Strategies for Learning Questionnaire (MSLQ), developed by the University of Michigan, will be used to measure student's motivational orientations and their use of learning strategies within the activity.

Materials

• Computers with the Internet connection (either PC or Mac)
• CReSIS animation
• CReSIS game application
• A pre- and a post test (the test includes six open-ended questions developed by CReSIS outreach coordinator Mrs. Hamilton)
• MSQL survey (condensed version with 25 questions)

APEENDIX C

Pretest

Name:

Class Period:

Pre - Test

1) Where are glaciers found today and where were they found 15,000 years ago? Sketch on the map of North America where the glaciers were and where they are now.

15,000 yrs ago

Now

2) How long does it take for snow to turn to firm? And firm to glacier ice? How does the warming of the Earth change this process?

Q1: __________

Q2: __________

Q3: __________

3) Identify three parts of a glacier (Points 5, 3 and 4).

P5: __________

P3: __________

P4: __________

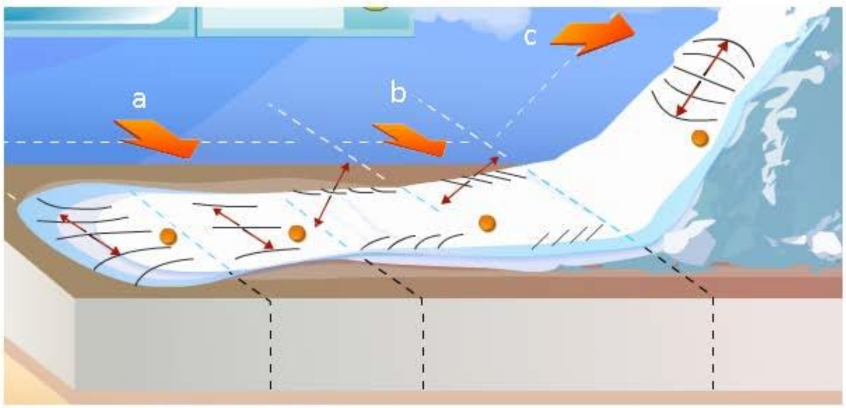
4) Name three landforms created by glacial movement.

1:

2:

3:

5) In the figure below, as seen in the animation in Ice on the Move, label each letter with a 1, 2 or 3 depending on which section moves the fastest (with 1 being fastest and 3 being slowest). Explain your choice for each letter in a short answer.



Explain your choice of each letter.

1:

2:

3:

6) Based on the map that you drew of the current state of the glaciers, what is your prediction of what will happen in the next 100 years to the glaciers? Support your answer with facts (2 to 3 minimum) learned from the lesson or other facts you have learned.

APPENDIX D

Posttest

Name:

Class Period:

Post - Test

1) Where are glaciers found today and where were they found 15,000 years ago? Sketch on the map of North America where the glaciers were and where they are now.

15,000 yrs ago

Now

2) How long does it take for snow to turn to firm? And firm to glacier ice? How does the warming of the Earth change this process?

Q1:

Q2:

Q3:

3) Identify three parts of a glacier (Points 5, 3 and 4).

P5:

P3:

P4:

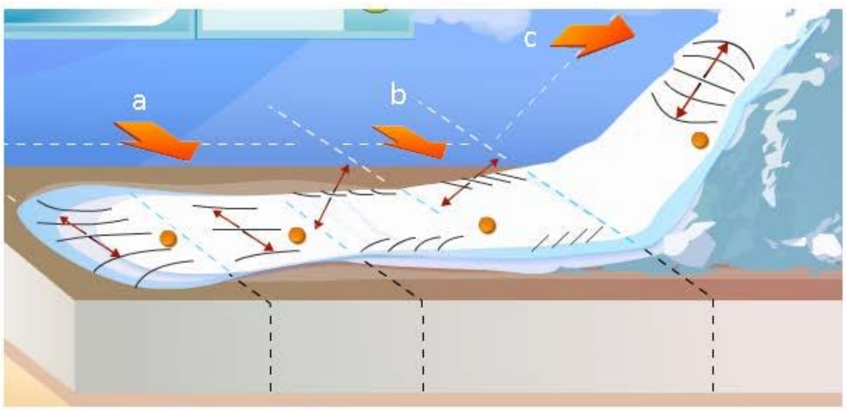
4) Name three landforms created by glacial movement.

1: ______

2: ______

3: ______

5) In the figure below, as seen in the animation in Ice on the Move, label each letter with a 1, 2 or 3 depending on which section moves the fastest (with 1 being fastest and 3 being slowest). Explain your choice for each letter in a short answer.



Explain your choice of each letter.

1: ______

2: ______

3: ______

6) Based on the map that you drew of the current state of the glaciers, what is your prediction of what will happen in the next 100 years to the glaciers? Support your answer with facts (2 to 3 minimum) learned from the lesson or other facts you have learned.

______

______

______

APPENDIX E

Scoring Rubrics

Name: ____________________

Class Period: ____________________

Study Questions

1) Where are glaciers found today and where were they found 15,000 years ago? Sketch on the map of North America where the glaciers were and where they are now.

2) How long does it take for snow to turn to firm? And then to glacier ice? How does the warming of the Earth change this process?

It takes snow to change to firn in about 10 years
It takes firm to change to glacier ice in about 15 to 100 years
If warming occurs, then the snow/firn could melt before it turns to glacial ice, which will not allow this process to happen.

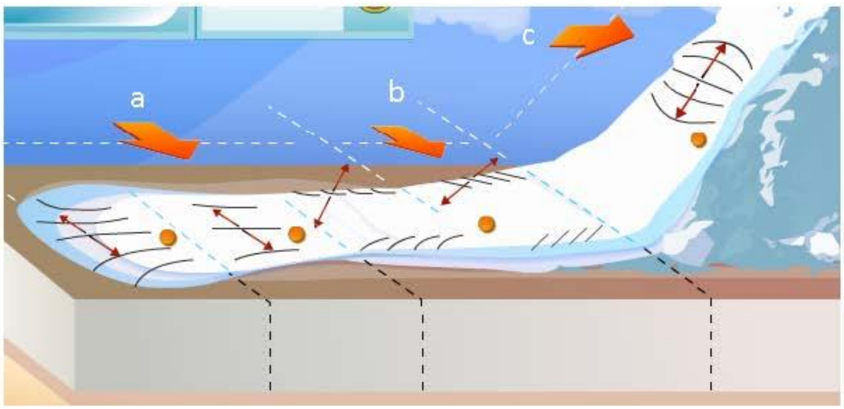
3) Identify three parts of a glacier (Points 5, 3 and 4).

5) Source, 3) Surface, 4) Base

4) How do glaciers change landscape? Name three landforms created by glacial movement.

Glaciers pick up or move rocks and soil by melting and refreezing.
Lakes, valleys, rivers or hills are landforms created by glacier movement.

5) In the figure below, as seen in the animation in Ice on the Move, label each letter with a 1, 2 or 3 depending on which section moves the fastest (with 1 being fastest and 3 being slowest). Explain your choice for each letter in a short answer.



a is 3, b is 2, c is 1
A is mostly flat, so it won't move to quickly, it is slowing down and spreading out
B is a moderate yet somewhat steady ice flow. The angle is not too steep, so it moves but not too quickly.
C is very steep, so that the ice/glacier accelerates and moves the quickest.

6) Based on the map that you drew of the current state of the glaciers, what is your prediction of what will happen in the next 100 years to the glaciers? Support your answer with facts (2 to 3 minimum) learned from the lesson or other facts you have learned.

They will disappear and be much smaller. In the last 15,000 years, they have shrunk, so they will continue to shrink. Global warming is a possible and good answer. Also, glaciers are moving and breaking and going downhill, where it is warmer in the valleys than in the mountaintops, causing them to be depleted too.

*Note, all questions are worth 3 points. The answers on the pretest and the posttest are graded according to this rubric. With the six questions, a total score of 18 points are available for each test.

Questions 1 and 6 are relating to history and how to analyze and interpret data from graphs and applying science for monitoring human impact on the environment (MS-ESS3-5)

Questions 2 and 3 are on the cycles of water in relation to glaciers (MS-ESS2-1 and MS-ESS2-4)

Questions 4 and 5 are on the physics of glaciers and how the mass and effects of gravity on the glaciers movement in their natural environment(MS-PS3-1)

Question Number	3 points – Excellent Answer	2 points – Moderate Answer or incomplete	1 point – Poor Answer or mostly incomplete	0 points – No answer or off topic/not relevant
1	All of the appropriate ice features are present, they show just how far south the glacier was and just how little of the glaciers are	The student may not show all of the ice, the ice 15,000 years ago may not be as far south and they may not have the glaciers of the	Missing a majority of the ice coverage of the history. If the history is like present day, this would be a 1. If students miss that	No response.

	left. Just in the high mountains in the Rocky Mountains and in Greenland.	Rocky Mountains today.	Greenland has glaciers today.	
2	Students explain that snow to firn takes about 10 years, and firn to glacier ice takes 15 to 100 years. They can relate that the warming of the earth doesn't allow for the snow to turn to firn and to ice.	Missing out on some of the years, if they are not exactly correct. Still need the relation to warming will not allow snow to turn to firn and ice.	Missing some of the years and the relation of warming won't allow for snow to firn to ice.	No response or off topic.
3	Correctly ID and label Source, Surface and Base.	ID two of the three	ID one of the three	ID none correctly.

4	Correctly state movement by melting and refreezing and give 3 landforms	They state melting and refreezing, but don't give 3 correct landforms	They only give landforms	Wrong response to all
5	Correctly ID that a is 3, b is 2 and c is 1. That A is mostly flat, B is moderately fast and C is steep.	They explain the quickest parts of the mountain correctly but don't label them as 1, 2 and 3.	They label a, b and c correctly, but don't explain their choice or their choices are incorrect.	No or wrong explanation, and they don't label the parts.
6	The student lists two to three correct facts about why glaciers are shrinking.	The student lists one fact about why glaciers are shrinking.	The student lists a partial reason for the shrinking of glaciers.	No or wrong response.

APPENDIX F

25-item Motivated Strategies for Learning Questionnaire

<table>
<tr><td>Name:</td><td>Age</td><td>1. Female
2. Male</td></tr>
<tr><td colspan="3">Ethnicity
1. Asian / Pacific Islander
2. Black or African American
3. Hispanic or Latino
4. Native American or American Indian
5. White
6. Other: ________________</td></tr>
<tr><td colspan="3">I prefer class work that is challenging so I can learn new things.
(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)
I am so nervous during a test that I cannot remember facts I have learned.
(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)
I am certain I can understand the ideas taught in this course.
(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)
I think I will be able to use what I learn in this class in other classes.
(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)
Compared with others students, I work harder than others to learn the materials.
(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)</td></tr>
</table>

I am sure I can do an excellent job on the problems and tasks assigned for today's class.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

I have an uneasy, upset feeling when I take a test.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

Even when I do poorly on the exit questions, I try to learn from my mistakes.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

I think that what I am learning in this class is useful for me to know.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

I think that what we are learning in this class is interesting.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

Compared with other students, I think I know a great deal about today's subject.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

I am confident that I will be able to learn the material for today's class.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

I worry a great deal about tests.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

While I am taking a test I think about how poorly I am doing.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

When I do the exit questions, I try to put together the information from the animation and from the gameplay.

(Strongly Disagree) < 1 2 3 4 5 6 7 > (Strongly Agree)

I ask myself questions to make sure I know the materials I have been studying.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

It is hard for me to decide what the main ideas are in what I just played.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

When work is hard I either give up or study only the easy parts.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

When I study I put important ideas into my own words.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

I always try to understand what the animation is teaching even if it doesn't make sense.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

When I answer the exit questions, I try to remember as many facts as I can.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

Even when study materials are dull and uninteresting, I keep working until I finish.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

I find that when playing the animation and glacier games I think of other things and don’t really pay attention to the content.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

When I am playing the animation I stop once in a while and go over what I have read.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)

I work hard to get a good grade even when I don’t like the classroom activities.

(Strongly Disagree) <   1   2   3   4   5   6   7   > (Strongly Agree)