Using the Four-Way Typology and Attitudinal Space Model to Examine Students' Attitudes toward Digital Game-Based Assessment

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Measurement, Evaluation, and Data Science

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Abstract

Background. Digital game-based assessment (DGBA) is a new and unprecedented generation of assessment that has rapidly developed in educational systems. Previous studies revealed that this modern assessment method could affect students' skills, motivation, and learning. Additionally, evidence-based studies demonstrated that simulated environments in DGBA could provide students with practical experiences to prepare them for real workplace requirements. Due to its benefits, researchers have focused on improving and developing DGBA in various educational subjects, including math, science, art, and social science. Also, researchers argued that DGBA could positively change students' attitudes toward academic subjects. However, previous studies focused on the "one- and two-dimensional perspective when assessing students' attitudes. Likewise, they did not focus on different attitude components (affective, cognitive, and behavioural) within the tripartite attitude system. Apart from other disparities in their findings, they did not examine which aspects of DGBA could predict students' attitudes.

Purposes. The primary purpose of this research was to cover areas not previously discussed in the literature, bridge the gaps in understanding students' attitudes toward DGBA, and examine the capacities of new models of assessing attitudes toward educational subjects. Accordingly, through using both the tripartite perspective of attitude and the four-way typology model of attitude, the current study aimed to examine how DGBA could affect students' knowledge and skill acquisition and their attitudes toward educational subjects. Additionally, the current research validated the Computer Game Attitude Scale (CGAS) for use in further studies.

Method. To achieve the goals of this study, two methods were utilized: a survey with questionnaires and a pre-and post-test approach with two separate groups of participants (Control and Experimental). Four hundred eighty-two students participated and completed the necessary questionnaires.

Data Analysis. Based on the research questions and the statistical nature of variables, different inferential statistical procedures, including Confirmatory Factor Analysis (CFA), MANOVA, MANCOVA, and Multiple Linear Regression, were employed to answer all research questions. **Results.** After playing the Graphing Slope-Intercept (GSI) game, the post-test differences between the Experimental and Control groups in their attitudes toward DGBA were significant. The finding indicated that playing the GSI positively changed the Experimental group's attitudes. Also, the within-group comparisons in the Experimental group revealed that the mean difference in the behavioural component of attitude in the pre and post-test was significant, and no significant differences in the Control group were observed. Unlike the Control group and after controlling covariates in the MANCOVA procedure, the results showed that the GSI affected all three components of attitudes in the Experimental group. Examining the characteristics of DGBA also showed that four elements of the GSI could attract participants' attention, including game rules, enjoyability, engageability, and understandability of content. Other mean comparisons revealed that the game of GSI could increase the positive cognitive and behavioural attitude of DGBA in the Experimental group. In addition, the results illustrated that GSI has a positive effect on improving students' knowledge and skill acquisition and a positive impact on their general attitudes toward DGBA. Finally, exploring the construct, the internal and convergent validity of the Computer Game Attitude Scale (CGAS) revealed that the CGAS could be used as a reliable and valid scale for further research.

Preface

This thesis is an original work by Mahnaz Shojaee. The research project of which this dissertation is a part received research ethics approval from the University of Alberta Research Ethics Board, Project Name “Using the Four-Way Typology and Attitudinal Space Model to Examine Students' Attitude toward Digital Game-Based Assessment,” No. Pro00114745, March 18, 2022.

Acknowledgements

I want to express my heartfelt thanks to my advisor and mentor, Dr. Ying Cui, for her unwavering support throughout my Doctoral study and related research. She has been patient, guiding, and motivating, which helped me complete this dissertation and develop the essential skills required of a researcher.

I am grateful to all the professors who provided valuable assistance, insightful comments, and motivation throughout my research journey. Their challenging questions encouraged me to explore various perspectives and areas beyond my initial focus.

Also, I am grateful for the unwavering reflective and emotional support that my husband, Mehrdad, has given me throughout all stages of my life. I would also like to express my gratitude to our daughter, Sana, and my parents for their encouragement, patience, and assistance over the years.

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Chapter I: Introduction

The increasing usage of the terms Technology-Based Assessment (TBA- Christensen et al., 2014), Game-Based Assessment (GBA- Stanescu et al., 2018), Video Game Assessment (VGA-Arias, 2014), and Digital Game-Based Assessment (DGBA- Denham, 2018) in the literature reveals that a new and unprecedented generation of assessments has rapidly developed in educational systems. This development has been remarkably stimulated by a growing tendency in game design companies to produce educational games in which the component of entertainment has also been embedded.

The market of games gained more than $43B from selling educational and non-educational digital games in the United States in 2019 (Entertainment Software Association - ESA, 2019). 2019 the global game industry generated US$152 billion in revenue (Entertainment Software Association of Canada - ESAC, 2019). This revenue revealed almost 27% growth from 2017 to 2019 (ESAC, 2019). A similar trajectory in revenue was found for Canada, with US $2.7 billion between 2017 and 2019, indicating 15% growth. Comparing the revenue of digital games between 2017 and 2019 revealed that the market is likely to continue with increasing investments in games globally (ESA, 2019).

Of all sold games, more than 80% were digital (ESA, 2019). Netscribes' Gaming Market Research (NGMR) is estimated to have a significant growth of 18.98% in the digital games market until 2022, leading to a global market size of $272.24 billion by 2022 (Global Digital Games Market, 2020). Regardless of the recession in the game industry because of the COVID-19 pandemic in 2020 and 2021, this growth was estimated to be 20% for the year 2025 (Mordor Intelligence, 2020). The Entertainment Software Association of Canada (2019) reported that active video game companies increased by 16% from 2017 to 2019, with a total number of 692 companies that produce different types of educational and non-educational digital games.

Almost 150 million Americans play video games, and 42% play regularly for at least 3 hours per week (Shute et al., 2016). Among different consumers, adolescents and young adults are the larger age groups eager to buy and play digital games (Arias, 2014; ESA, 2019). Lenhart et al. (2008) reported that almost 97% of adolescents and young adults (secondary and post-secondary students) in America use digital games.

In Sweden, Mathe et al. (2019) reported that 87% of youth between nine and 12 years old spend, on average, between five and seven hours per week playing digital games. In Canada, the Office of the Privacy Commissioner of Canada (OPCC - 2019) reported that not only 71 percent of Canadian parents play video games weekly with their children, but also 80 percent of Canadian parents thought that gaming is one of the mainstream entertainment that can have educational roles.

Scrutinizing parents' attitudes toward using digital games revealed that parents are positive influencers in presenting games in their children's life (OPCC, 2019). In America, nearly three-quarters (74%) of parents believe video games can be educational for their children. In contrast, more than half (57%) enjoy playing games with their children at least weekly, which may strengthen positive family relationships (ESA, 2019). Hussain and Griffiths (2009) emphasized such positive psychological effects of games. They reported that gamers could improve their social relationships, knowledge about other cultures, friendships, and teamwork through digital gaming. Also, gamers said their computer skills, typing, reading comprehension, economics, and mathematics skills were efficiently improved (Hussain & Griffiths, 2009). In their systematic review of 50 studies on digital card games, Kordaki and Gousiou (2017) revealed that parents reported a positive attitude toward using games in learning and assessment.

Parents' positive attitudes towards games and market influences encouraged researchers to study the various implications and aspects of educational digital games on assessments (Hebert & Jenson, 2018; Turan & Meral, 2018; Wang, 2018). These implications include the efficacy and maneuverability of computerized test administration (Martin, 2008), automated scoring, increased objectivity through 2-D and 3-D simulations, and immediate feedback (Pasztor et al., 2015; Redecker, 2013). Apart from these advantages, the following section lists several factors that crystalize the necessity and importance of educational digital games, particularly DGBA.

The Necessity and Importance of DGBA

Through an investigation of 3000 articles, Arias (2014) scrutinized 54 articles related to GBA, DGBA, GBL, and Video Games. They reported several benefits of using such games in the education of social studies, natural science, language, and physical education (Table 1).

Table 1
Benefits of digital games in educational subjects (Adapted from Arias' research, 2014)

Subject Areas	**Video Games or Digital Games for learning subject**	**Benefits**	**Researchers**
Social Studies			
	World of Warcraft (WoW)	Authentic opportunities for empirical thought	(Steinkuehler & Duncan, 2008)
	Second Life (SL)	Increasing deeper learning	Atkinson (2009; cited in Dubas & Hill, 2013)

	Making History	Providing a learner-focused environment instead of a teacher-focused lecture	(Watson et al., 2011).
	Civilization III	A better understanding of interdisciplinary subjects (relationships between geography and politics, economics and history, or politics and economics)	(Squire et al., 2008; cited in Arias 2014)
	Pax Warrior	Acting as participants in the United Nations to make decision during the genocide in Rwanda. Discovering novel solutions, they had not thought of in previous decisions of the topic.	(Carpenter et al., 2008)
Science			
	Quest Atlantis (QA)	Developing a rich perceptual, conceptual, and ethical understanding of science. Improvement in academic achievement.	(Barab et al., 2007)
	Dr. Friction	Significant learning about the concept of friction and motion.	(Annetta et al., 2009)
Language	*The Sims*	Useful opportunity for language learning.	(Ranalli, 2008)
	Quest Atlantis (QA)	Better understanding the meaning of terms.	(Zheng et al., 2009)
Physical Education	*Nintendo Wii and PS3's Move*	Increasing in balance measures. More engagement.	(Vernadakis et al., 2012)

In addition to Arias' research (2014), at least six significant benefits of using digital games in educational subjects were discussed in the literature. First, games promote students' affective and cognitive capacities. In its report, ESA (2019) argued that digital games could provide students with mental stimulation, relaxation, and stress relief (ESA, 2019). Also, it was demonstrated that students' learning and cognitive skills, such as controlling episodic memory, could be positively affected by digital educational games (Colzato et al., 2010). Likewise, digital educational games can help students' mental health (Ferchaud et al., 2020; Namli & Demir, 2020) and academic performance directly or indirectly (Al-Azawei et al., 2019; Arias, 2014).

Second, students' skills need to be compatible with the essential requirements of workplaces. Several companies highly recommended this compatibility, namely Cisco, Intel, and Microsoft (Griffin & Care, 2015). To provide this compatibility, DGBA and DGBL can provide students with authentic experiences in a natural context to acquire the workplace requirements (Al-Azawei et al., 2019; Arias, 2014). However, providing a real context needs to study the students' skills and attitudes on the one hand and the workplace requirements on the other hand.

Third, researchers argued that DGBA has potential capacities for educators to develop and facilitate students' learning (Plass et al., 2015; Wang, 2018) and to advance the assessment of student's knowledge or performance in various fields, such as chemistry (Annaggar & Tiemann, 2017), math, physics, social studies, language (Arias, 2014), science (Chu & Chiang, 2018; Cui et al., 2019), personality (McCord et al., 2019), and medicine (Maganty et al., 2018). DGBA has also been used to assess students' psychological skills, such as social-emotional or problem-solving skills (Annaggar & Tiemann, 2017; DeRosier & Thomas, 2018). Since fostering students' skills is vital with digital innovations in the 21st century, An and Cao (2017) demonstrated that digital games hold the necessary potential to foster such skills. One of the skills in this regard is mastery in science, technology, engineering, and mathematics (STEM-Shojaee et al., 2019). In contrast to traditional methods in STEM, digital games can integrate the subjects of STEM to provide a semi-workplace environment and facilitate authentic and deep learning and reliable assessment (Chu & Chiang, 2018). In this regard, a digital game may help students to discover information, rules, and ideas pragmatically (Wang, 2018). Shute and Emihovich (2018) argued that using games in education can fill the gap between the kinds of problems taught in schools and what is required in the workplace.

Fourth, focusing on DGBA, Hebert and Jenson (2018) argued that traditional assessments, such as pencil and paper assessments, are limited since such methods cannot assess different types of knowledge requiring multimodal competencies. Some skills, such as divergent thinking, are also difficult to assess by traditional methods because traditional open-ended tasks generate numerous responses and coding, scoring, and analyzing those responses are time-consuming and erroneous (Pasztor et al., 2015). Instead, some cognitive or emotional skills (e.g., problem-solving skills) can be assessed or taught through DGBA methods authentically and precisely because they can provide the simulation of different emotional, situational, technical, physical, and theoretical aspects of tasks. Shute and Emihovich (2018) argued that game-based assessments not only promote problem-solving skills through transferring content knowledge into novel contexts, but they can also link school curricula to real workplaces. This capacity has helped students to analyze and solve complex problems in workplace contexts (Shute et al., 2018).

Chan and Ismail (2014) demonstrated that traditional assessments (e.g., true-false or multiple-choice assessments) are weak in portraying a wealthy evaluation of students' performance and efficacy in statistics. They also argued that understanding statistical concepts such as frequency, central tendency, variability, and distribution can be facilitated by technology-based assessments. Such statistical concepts need a reasoning framework that these new ways of evaluation can facilitate. Statistical reasoning is how individuals ratiocinate with statistical concepts to grasp and express the meaning of information (Beshlideh, 2012). Through experimental research, al-Azawei et al. (2019) compared the Moodle quiz tool with the Virtual Reality game-based assessment system (VR-GBA). They found that students perceived VR-GBA as much more playful and easier to use.

Fifth, DGBA can enhance students' motivation, engagement, and academic achievement (Adesoji, 2008; Bovermann et al., 2018; Turan & Meral, 2018). Wang (2018) argued that using digital games in education can improve students' experiences and engagement in learning and assessment. Focusing on math, Abrams (2008, as cited in Mahmoudi et al., 2015) argued that computer games are solid motivational tools for learning mathematics. Also, Ke (2008, as cited in Mahmoudi et al., 2015) demonstrated that such games could motivate students to learn math better than traditional methods. Bovermann et al. (2018) explained that using games in education can foster students' motivation and changes in their learning behaviours.

Through a quasi-experimental design, Turan and Meral (2018) used an online game-based assessment called *Kahoot*. They found that game-based assessment increased student achievement and engagement and decreased test anxiety. Adesoji (2008) also demonstrated that games have several positive attributes in teaching and assessment, such as enhancing students' motivation. This is because traditional assessment is not as attractive as DGBA to engage students in multi-authentic tasks. In contrast to traditional assessment, game-based assessment can foster students' motivation and academic achievement (Bovermann et al., 2018).

Distinguishing GBA (which can be used without digital devices) from DGBA, Heinzen (2014) argued that DGBA can be effective in fostering students' motivation and academic achievement since it can provide students with predictable and constructive feedback, engage them by using points as rewarding motivators that increase their immediate pleasure of success and reduce their test anxiety. Heinzen (2014) emphasized that using DGBA can create an opportunity for teachers to have more meaningful assessments because games allow students to earn as many points as they care to complete the assignment. Through digital games, students can help each other when they work together and will know whether they are failing or succeeding. These features can increase students' learning through assessment. Developing a framework of virtual exhibitions by integrating the Unity Game Engine with a novel 3D Janus Virtual Reality browser, Wang (2018) examined the students' improvement in learning history and found that students had improved more significantly than those who used traditional methods.

Sixth, games integrate learning and assessment. Traditional summative and formative assessments focus on assessing students' learning at a particular time (Kuo & Wu, 2013). The learning and assessment processes in traditional methods are separate from each other. In contrast, a deep understanding of the learning process can be achieved by integrating learning and assessment in a single process. The technology of 2D/3D simulation and virtual reality in DGBA, GBL, or VGA can provide educators with an opportunity for such integration, so students can learn and be assessed concurrently.

This process usually presents several questions organized based on students' answers to previous questions with an opportunity to correct their mistakes. One example of this integration can be found in *Posterlet* (Cutumisu et al., 2015; Cutumisu et al., 2019). *Posterlet* is an assessment game where students learn how to design posters while evaluating their performance. Another example is the game of *Raging Skies* (Chu & Chiang, 2018; Cui et al., 2019), which was used to assess the mastery of content knowledge and process skills in one specific subject in science. Chu and Chiang (2018) used *Raging Skies* in their research. They found that students could engage in the learning and assessment process of identifying principles, implementing them, and conducting inquiry about content knowledge and process skills. Such digital games are innovative in integrating learning and assessment (Oblinger, 2004).

Although these benefits can justify the role of DGBA and DGBL in different areas (e.g., promoting cognitive and affective skills, learning, and assessment), researchers suggested that to realize such benefits, the various aspects of educational games (e.g., DGBA) should be studied by using the method of "attitude assessment" (Cankaya & Karamete, 2009; Demirbilek & Tamer, 2010; Mavridis et al., 2017).

Implications of Attitude Assessment in DGBA

Attitude assessment was used to optimize the content of digital educational games (Hebert & Jenson, 2018; Turan & Meral, 2018) and to improve the curriculum. For example, Demirbilek and Tamer (2010) examined teachers' attitudes toward using DGBA in the Math curriculum. They found that integrating DGBA into the Math curriculum "could improve students' creativity, allow students to participate in lessons actively, develop Math vocabulary, and comprehend the Math concepts easily" (p. 1).

Moreover, examining students' attitudes toward educational systems was emphasized globally. The Council of the European Union (CEU, 2006 as cited in Redecker, 2013) introduced eight primary competencies, such as mathematical, scientific, and digital competencies for lifelong learning, as major tasks for educational systems. These competencies were defined as a combination of knowledge, skills, and attitudes that students should acquire for the future. In addition to CEU, the Organization for Economic Co-operation and Development (OECD, 2018) outlined the "Future of Education and Skills 2030". In this outline, students' attitudes and how they have been affected by instructional methods (learning and assessment procedures) were emphasized as the significant purposes for the education of 2030. These outlines express students' attitudes as a broad view toward education, schooling, environment, and community.

Students’ attitudes are deemed as significant components that interplay in all forms of interactions (e.g., static, active, and interactive) among students’ performance, feelings (e.g., test anxiety, frustration, excitement, or enjoyment), and new instructional methods, such as DGBA, DGBL, and VGL.

While the ‘static’ form of interaction is very similar to traditional learning and assessment, the ‘active form’ includes pictures, portrayals, animations, and other dynamic types of items in DGBA, and the ‘interactive form’ is a cooperative style through which students’ responses to one item will determine the type of next item (Quellmalz et al., 2013). Students’ attitudes can be used to evaluate different aspects of DGBA (e.g., structure, content, and dynamic) and examine whether the educational games can change their perceptions (attitudes) of educational subject matters. For example, Najdi and El Sheikh (2012) reported that we could postulate how digital educational games are well-organized and well-planned through students' attitudes. Also, Mavridis et al. (2017) demonstrated that digital educational games could positively change students’ perceptions of mathematics. In addition to these positive roles of attitude assessment, there are several other implications of attitude assessment in digital educational games.

Structure and dynamics of DGBA and attitudes

The structure of DGBA refers to several mechanical features, such as mobility capacities, wireless interfaces, independence, omnipresence, and built-in sensors (Giannakas et al., 2018). The dynamics of DGBA are also related to game elements, such as points, stages, figures, motion, badges, prizes, progress bars, storyline, animation, and leaderboards (Ahmed, 2020; Aldemir et al., 2018). It is suggested that the interrelationships among these elements can be determined and optimized by assessing students’ attitudes to the appropriateness of such features. In addition, evaluating students' attitudes toward the elements and the structure of DGBA will provide the researcher with information about whether DGBA is similar to a traditional test and whether its elements are well-structured or ill-structured.

Instructional content of DGBA and attitude

As abovementioned, Evidence-Centered Game Design is an approach to unifying the content of knowledge and assessment into game structure. However, one of the critical issues in DGBA is the extent to which content knowledge can be authentically translated into games (An & Coa, 2017). Facts, concepts, propositions, rules, terminology, definitions, assumptions, formulas, maps, and other parts of a targeted math or science content should be designed and integrated with gamification precisely to provide students with a more enjoyable, authentic, and simulated learning and assessment environment. Yildirim (2017) defined gamification as using game elements in digital forms for different aims in non-game contexts, such as marketing, employee training, and education. Thus, students' attitudes are sources of potential information to evaluate this linkage and to justify whether there are any possible errors in translating the content knowledge into games. Students' attitudes can also determine the suitability, pedagogical value, relevance, and authenticity of digital game-based assessment content knowledge.

Attitude and Engagement with DGBA

Recent studies reported that various GBA, GBL, and DGBA affected student motivation and engagement positively (Adesoji, 2008; Bovermann et al., 2018; Turan & Meral, 2018). Such results were obtained using different methods to assess students' engagement in game-based learning or DGBA (Butt, 2016; Turan & Meral, 2018). For example, analyzing data about the time students spent completing game tasks or responding to questions, Hebert and Jenson (2018) exemplified students' engagement in DGBA. Also, Butt (2016) examined students' attitudes and found that a more positive attitude was associated with more engagement in educational games.

DGBA and Attitude Prediction

Students' attitudes may play a predictive role in their performance (e.g., achievement of content knowledge), feelings (e.g., test anxiety, frustration, excitement, or enjoyment), and digital experiences related to DGBA. For example, Chinomona (2013) studied the predictive role of students' attitudes in the relationship between perceived enjoyment, perceived ease of play, and gaming continuance intention. He found that perceived enjoyment had a more substantial effect size in predicting mobile gaming continuance intention through the positive role of attitude (Chinomona, 2013).

However, existing studies did not examine which features of DGBA can attract students' attention and predict their attitudes directly. Also, they did not examine the tripartite attitude model discussed by Haddock and Maio (2008), Ibuot (2020), and Liu (2020) in their predictive studies. In the tripartite model, attitude is defined through three significant components, cognitive, affective, and behavioural (Haddock & Maio, 2008; Ibuot, 2020; Liu, 2020). Based on the tripartite attitude model (see Chapter II for more details), perceived enjoyment is related to the affective component, and gaming continuance is seemingly associated with the behavioural component of attitude. Affective and behavioural components are two aspects of one construct. Moreover, previous studies were less focused on interrelationships among students' attitudes toward DGBA, game and computer experiences, the level of engagement in the subject matter, and knowledge and skill acquisition. They also did not examine which characteristics of DGBA (e.g., engageability, enjoyability, game rules, and understandability) could significantly predict students' attitudes toward DGBA.

Concerning the implications of measuring students' attitudes toward DGBA, the previous studies were reviewed in more detail in chapter two (literature review) of this thesis research. This exploration helped the researcher to recognize the gaps or disparities among previous studies, clarify the purposes of current research, and formulate the research questions of this thesis. The following definitions of contributing factors will guide the audiences in figuring out the literature review's scope.

Key Definitions

Digital Game-Based Assessment

Digital game-based assessment (DGBA) is a generic term with different forms and involves different digital device types, such as computers, tablets, and mobile cells (Shute et al., 2016). It refers to utilizing any digital educational games played online or through other platforms to teach diverse types of subjects and to assess student's learning performance and behaviours (Marti-Parreño et al., 2018; Shute et al., 2016).

Attitude

Attitude is a cognitive, emotional, and behavioural reaction or evaluation the individuals have toward any object, subject, event, or fact (Aydin, 2012, cited in Han & Carpenter, 2014; Haddock & Maio, 2008). This evaluation can be different based on the "components," the "valence" (positions), and the "strength" of attitude toward an object such as a specific DGBA.

Knowledge and Skill Acquisition

It refers to acquiring knowledge about a specific subject matter and using the related knowledge in a real situation (Steinmayr et al., 2015). Knowledge and Skill Acquisition (KSA) is usually measured using different ways, including scales, performing assignments, or teacher-made questionnaires (Saadat et al., 2012). Also, it may be assessed by asking students to determine their knowledge of a specific subject matter on some self-report questions (Pittman & Richmond, 2007). In this thesis research, KSA will be measured through a prior knowledge questionnaire about GSI (University of Colorado Boulder, 2021).

Chapter II: Literature Review

This chapter revolves around the current knowledge about the developmental history, nature, and characteristics of digital game-based assessment (DGBA). Additionally, the roles of attitude assessment in optimizing the structure, content, and dynamics (gamification) of DGBA in educational settings will be explored. Chapter two will also provide information helpful to explicate the previous orientations in studying students' attitudes toward DGBA. The purposes of the current study and the research questions will be formulated by elaborating on gaps and disparities in the previous studies.

Digital Game-Based Assessment

Developmental History of DGBA

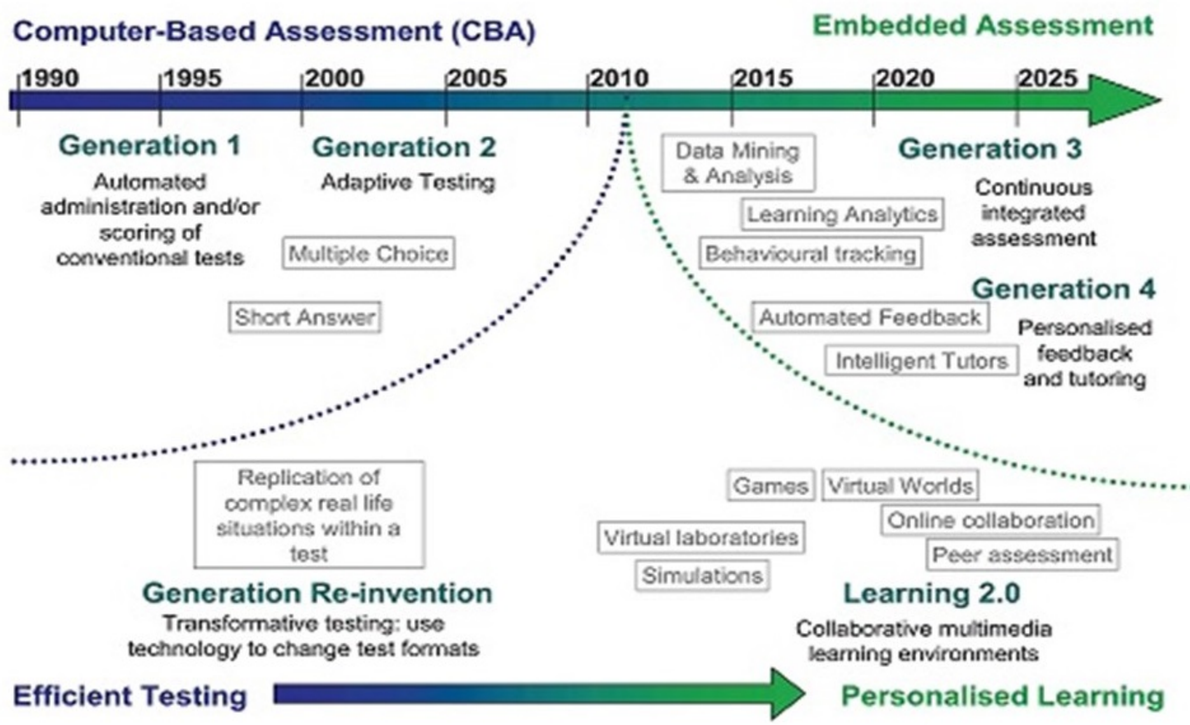
The history of DGBA is blended into the invention and development of the computer, which has a long history with different milestones. Although the first computer was the Electronic Numerical Integrator and Calculator invented in 1943 in America as a programmable, electronic, and general-purpose digital computer (Zimmermann, 2017), it was reported that Sidney Presses developed automatic testing in 1920 as the first attempt to start electronic assessment in education. From 1943 to 1960, computers were inefficient for educational purposes (Shute & Rahimi, 2016). From 1960 to 2000, several operating systems and the Internet were invented, making computers more powerful.

The rapid developments in computer systems from 1990 to 2000 increased the compatibility of digital technology to be used in the various aspects of human life, such as marketing, entertainment (e.g., creating games), education, engineering, and medicine (Namli &

Demir, 2020; Redecker, 2013). Since 1990, different generations of using digital assessment have been reported by Redecker (2013). These generations are portrayed in Figure 1.

Figure 1

Overview of Historical Trends and Developments in Technology-Based Assessment



Note. Adapted from Redecker, 2013 p. 5. Historically, four generations of technology-based assessment from 1990 to 2025 have been recognized.

As Figure 1 shows, in this historical line, four generations were recognized. The first generation (from 1990 to 2000) was related to automated administration and scoring assessment tools. The second generation (from 2000 to 2010) of assessment used an adaptive testing method. After administering each question, the student's skill levels are recalculated and estimated in adaptive tests. This process helped the system choose items based on the student's ability or performance (Redecker, 2013).

The third generation (from 2010 to 2020) of technology-based assessment (TBA) was related to continued integrated assessment in which both formative and summative assessments were integrated. Also, the fourth generation (from 2020 to 2025) refers to personalized learning and assessment and using a collaborative multimedia environment (e.g., digital games). During the third and the fourth generations of TBA (from 2010 to 2020), the role of using games (gamification through virtual technology) for educational aims has been importantly recognized (Arias, 2014; Denham, 2018; Namli & Demir, 2020; Redecker, 2013).

Historically, the emergence of digital games in education was under the influence of Piaget's (1973) cognitive theory. Although there were other educational and psychological theories regarding play and its educational effects (Al-Azawei et al., 2019; Arias, 2014; Hellerstedt & Mozelius, 2019), Piaget's theory empathized game as a vital factor in individuals' cognitive development (Dag et al., 2021). Although several factors influence human development through lifespan, games can facilitate the process of assimilation and adaptation. This process is an interaction between the individual and the environment through which the individual receives knowledge from the environment and changes their cognition to have better adaptation (Dag et al., 2021). This theory is a kind of game-based learning theory through which a game can combine different integrated learning elements such as motivation, interest, immediate feedback, challenging content, curiosity, and imagination (Zhong, 2019). Based on this theory, simulation and virtual reality in educational games can improve students' cognitive competency and provide them with more realistic and authentic experiences.

This recognition, in the decade of 1990, motivated researchers to introduce new virtual applications to higher education, such as *Safety World, Science Space,* and *Virtual Gorilla Exhibit Change* (Merchant et al., 2014) that displayed the feasibility of using such games in the context of learning and assessment (Al Azawei et al., 2019).

In addition to such theoretical influences, the role of marketing in promoting digital games for educational purposes has been predominant during the decades of 1990 and 2000 (ESA, 2019; Griffin & Care, 2015; Marti-Parreno et al., 2018). It was argued that in 2008, Cisco, Intel, and Microsoft offered educational systems to improve students' skills and to educate students in a way compatible with the new requirements of digital workplaces (Griffin & Care, 2015).

In this context, digital games were claimed to have several advantages (Hebert & Jenson, 2018; Turan & Meral, 2018), such as providing students with authentic experiences through working with the simulated world (Wang, 2018) or enhancing students' motivation (Bovermann et al., 2018; Lepper & Greene, 1975; Wang, 2018). Mark Lepper and Thomas Malone's (1975 to 1980) work on students' engagement and motivation using computer games (Hellerstedt & Mozelius, 2019) were some of the primary evidence-based studies for such claims. Numerous recent studies highlight such advantages (Hebert & Jenson, 2018; Turan & Meral, 2018; Wang, 2018). However, as digital technologies have been developed gradually, three historical trajectories can be considered for DGBA.

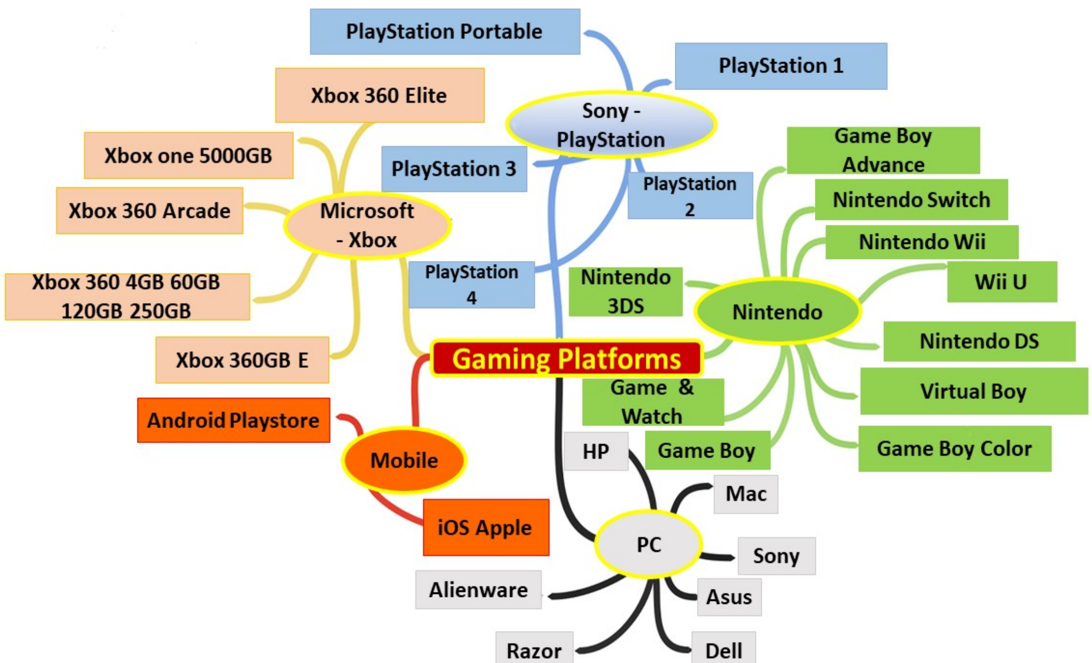
Three Historical Trajectories. According to Merchant et al. (2014), the first trajectory relates to digital games designed in early 1990 in a 'static' form, such as *Safety World*, *Science Space and Virtual Gorilla Exhibit Change.* This form was a pictorial game similar to traditional teaching and assessment tools but delivered with a digital tool (Holmgren & Ståhl, 2016). The second trajectory refers to video games with more 'active' components, such as *Quest Atlantis* (Barab et al., 2007). In this form, portrayals, animations, and other dynamic items create an active game environment (Holmgren & Ståhl, 2016). The third trajectory is related to the 'interactive' versions of digital games such as *Raging Skies* (Chu & Chiang, 2018; Cui et al., 2019) and *Graphing Slope-Intercept* (GSI-University of Colorado Boulder, 2021) in which the users face an interactive environment to learn and respond to questions based on the pictorial storyline. Also, students usually control the program's storyline through their activities.

In addition to these developmental trajectories of digital games, it was also argued that educational systems followed three strategies in using digital games (Marti-Parreno et al., 2018). The primary strategy was focused on some commercial digital games that could be used for educational purposes as "extra activities." Games such as World of Warcraft were not purposefully made for education in this strategy. The second strategy was to use digital games built with the primary goal of learning, such as *Blokify*. The third strategy was related to using games that were purposefully made for teaching or the assessment of specific competencies, such as problem-solving skills, critical thinking skills (Van Eck, 2006 cited in Marti-Parreno et al., 2018), or learning a particular subject matter such as Raging Skies (Cui et al., 2019).

Although there is not a chronological line for these strategies, it seems that through the development of digital devices, the third strategy and the interactive form are the most recent ones that have two major characteristics: a) they are built for a specific educational purpose such as GSI (University of Colorado Boulder, 2021) and b) they have more active or interactive structures based on the most developed platforms such as mobile platform (Giannakas et al., 2018). Figure 2 shows different platforms on which digital educational games for learning and assessment are being made and used.

Figure 2

The Popular Platforms of Digital Games Used in Education



Note. Adapted from Coggle.it, 2021. Five popular platforms are being used for playing digital games, including mobiles or cellphones, PC or laptops, Nintendo, Microsoft-Xbox, and Sony PlayStations.

The Potentials of DGBA

DGBAs are typically subject-based with specific and common characteristics. As a new generation of assessment tools, the term digital game-based assessment has three main integrated aspects including the *mechanical (structural)*, which is related to the features of digital technology; the *content*, which refers to learning or assessment contents; and *gamification*, which is related to dynamic features of the game. Each aspect of DGBA has various but integrated features (Figure 3). The first aspect of DGBA, the *mechanical,* characterizes the structure of DGBA that is related to those digital applications, services, tools, devices, or resources that are applied to find, analyze, create, communicate, and use information in a digital context (Scottish Government, 2016). The digital context means binary computational code used in some devices (e.g., mobile phones, tablets, laptops, and computers).

The second aspect of DGBA, the *content*, which characterizes the content or subject matter of DGBA, is the subject of learning or assessment. The term assessment has various meanings (Bachman, 2004; Ghaicha, 2016). However, assessment can be defined as a systematic process of collecting and interpreting information about the content of knowledge, behaviour, learning, experiences, performance, skills, attitude, or other cognitive and emotional competencies of a group of people such as students, employees, or patients (Corsini, 2002; Yambi, 2018). Regarding DGBA, Baker et al. (2008) explained assessment as a systematic observation that uses a technological format and gamification to demonstrate accomplishment in a specific domain. Accordingly, the role of assessment in DGBA is to provide information through a game system (digital game) to understand learners' or students' experiences, needs, performances, and competencies (Kickmeier-Rust, 2018).

The third aspect of DGBA, the *gamification*, characterizes the dynamic processes of DGBA. This aspect refers to those game elements or influencers embedded dynamically in digital devices (technology) to pursue educational or non-educational aims. Bovermann et al. (2018) stated that gamification involves incorporating game-like features into digital technology, although a universally accepted definition of game-like features does not exist. Such elements are exemplified as time, space, rules (Kordaki & Gousion, 2017), rewards, teams, win-state, storyline, quest (Aldemir et al., 2018), points, badges, leaderboards and progress bars (Aldemir et al., 2018; Bovermann et al., 2018). These elements may motivate individuals to achieve their goals (Aldemir et al., 2018), to promote their learning and solving problems (Giannakas et al., 2018), or to enhance their cognitive and emotional engagement in educational or non-educational contexts (McCord et al., 2019).

When these three aspects of DGBA, mechanical, content, and gamification, are incorporated into each other to create a specific DGBA (such as GSI- University of Colorado Boulder, 2021; *Second Life* - Atkinson, 2009, cited in Dubas & Hill, 2013; or *Raging Skies* - Chu & Chiang, 2018; Cui et al., 2019), a set of beneficial characteristics (outcomes) will emerge that is not in traditional assessment. These characteristics are related to the structural, contextual, and dynamic processes of DGBA.

Structural or Mechanical Characteristics of DGBA. These features refer to the capacities of various digital devices used in designing, unifying, and implementing games and the subject matter of assessment. Each digital device, such as mobile, computer, and tablet, has its capabilities; however, they have several common characteristics. These characteristics determine the mechanical elements or the structure of DGBA. For example, suppose the mobile platform (Figure 2) is used in DGBA and game-based learning. In that case, mobility capacities, wireless interfaces, independence, omnipresence, and built-in sensors can provide educators with blended and context-sensitive mobile activities for learning (Giannakas et al., 2018) and assessment.

Ogata and Yano (2004, cited in Giannakas et al., 2018) argued that these capacities might create several outcomes, such as permanency, accessibility, and interactivity. Giannakas et al. (2018) pointed out spatiotemporal as a dimension of digital mobile devices that is referred to space, location awareness, and time. This dimension is related to the structural features of digital devices, such as mobile that make them effective in learning and assessment.

This characteristic allows modern digital devices like mobile devices to place learning and assessment experiences in an authentic context, anywhere and anytime. This characteristic provides users with easy navigation through the contents of scenarios. For example, Sanchez et al. (2006, cited in Giannakas et al., 2018) developed *BuinZoo*, a digital game, to support students' navigation in a zoo. In this game, users can utilize a virtual map to move around and receive appropriate information about the animals and their physical location. Then, they can answer questions that help them recognize each animal and its habitat. Likewise, *Blatannkoden* is another DGBA that involves a treasure-hunting scenario. This game was designed to help secondary school students physically navigate and explore a museum or any tourist place (Ceipidor et al., 2009, cited in Giannakas et al., 2018). Giannakas et al. (2018) argued that the structure of such digital devices could locate the users and physical places close to one another, as well as players and artifacts.

Different types of navigation were also pointed out by Mousa (2017). He explained that digital devices in game-based assessment could allow users to navigate among their responses, correcting and retracing their steps (backtracking). Digital technology can also create an interactive and immersive virtual environment where individuals can freely work on tasks and receive immediate feedback (de Klerk & Kato, 2017).

Apart from the above-noted structural characteristics, the mechanical aspect (digital technology) can locate or store the users' responses in a secure place using password-based authentication and authorization (Giannakas et al., 2018). Thus, the user's data will be protected from unauthorized third parties, resulting in secure communication and data access. Also, automated scoring is provided by the architecture of such digital devices (Redecker, 2013; Pasztor et al., 2015). It is also argued that automated scoring can facilitate score extraction, evaluation, and accumulation in DGBA (Redecker, 2013). Automated scoring may provide a possibility to reduce the time and costs associated with the assessment of complex skills and enhance the precision and objectivity of DGBA's outcomes.

Another essential feature of DGBA is sufficient contrast between background and text. This feature (as the mechanics of digital devices) can facilitate the assessment process for individuals with disabilities (Salend, 2009). Students needing to be more comfortable with traditional assessments can use DGBA for their exams. Through this, they can adjust colour schemes, layouts, and font size to make the screen more readable. These structural features of DGBA can help students with disabilities and non-disabled students to use DGBA easily (Christensen et al., 2014).

Content-Related Characteristics of DGBA. These features are related to the types of contexts or the subject matters of assessment in DGBA, such as the formats of assessment, the positioning of the subject matter, storyline, questions, or purposes in DGBA. Such elements provide students with knowledge, experiences, and value. More advanced than traditional ways of assessment, computer-based assessment can be an alternative, direct, or authentic assessment since it has enough compatibility with different subject matters and assessment formats such as written products, portfolios, checklists, multiple-choice items, and others (Olfos & Zulantay, 2007). Compared with other types of technology-based assessment, DGBA has more technological compatibility to embrace diverse subject matters, such as thematic subjects in social studies that are seen in *World of Warcraft* (Steinkuehler & Duncan, 2008), *Civilization III* (Squire et al., 2008; cited in Arias, 2014), and *Blatannkoden* (Ceipidor et al., 2009, cited in Giannakas et al., 2018). As well, the subject matter in natural science, as seen in *Raging Skies* (Chu et al., 2018; Cui et al., 2019) or mathematic subjects, as seen in *Dr. Friction* (Annetta et al., 2009) and *GSI* (University of Colorado Boulder, 2021).

In GSI, the content embraces graphical interactive elements to teach and assess the subject of line equations and slope-intercept in statistics and math (University of Colorado Boulder, 2021). The relationships between geography, politics, economics, and history were precisely embedded in Civilization III (Squire et al., 2008; cited in Arias, 2014). In *Raging Skies* (Chu et al., 2018; Cui et al., 2019), the subject of weather watch was embedded to teach and assess students' related knowledge and performance. Dr. Friction (Annetta et al., 2009) was also built for training and evaluating the concept of friction and motion in science, or *Quest Atlantis* for learning and evaluating language terms in language courses (Zheng et al., 2009).

These examples show that the contents of assessment in DGBA can be precisely defined, maximally accessible, simple, clear, and highly readable for students (Christensen et al., 2014; Chu et al., 2018; Cui et al., 2019). Such capacities maximize the compatibility of DGBA to integrate diverse subject matters (educational tasks), methods of assessment, and users' needs to assess various students' competencies, behaviours, or skills (Giannakas et al., 2018; Shute et al., 2016; Stoeffler et al., 2019).

For example, *Circuit Runner was a game-based assessment* to train and assess collaborative problem-solving competency (Polyak et al., 2017). Collaborative problem-solving is "knowledge, skills, and behaviours required to effectively participate in a joint activity requiring interdependence among participants to transform a current state to a goal state" (Stoeffler et al., 2019, p. 2). Based on this definition, *Circuit Runner* was designed to incorporate different tasks to assess collaborative problem-solving skills such as strategy, perspective-taking, problem feature awareness, communication, commitment, problem orientation, goal orientation, strategy, execution, and monitoring and evaluation (Polyak et al., 2017; Stoeffler et al., 2019).

Apart from these capacities in DGBA, the subject matter of a game can be personalized based on students' abilities and experiences (Giannakas et al., 2018). This personalization is possible when the contents and the assessment items are designed for different difficulty levels, helping educators to control and develop students' progress (Mousa, 2017). Perhaps making the contents of DGBA more personalized (Giannakas et al., 2018) can be considered an outcome of parametrizing the level of difficulty of contents. This personalization in which the students' needs are considered can make the contents of DGBA more reconcilable with students' backgrounds and experiences.

Additionally, de Klerk and Kato (2017) pointed out that it is possible to integrate both formative and summative assessments within DGBA by which students' achievement can be monitored. Using both summative and formative assessment was previously practiced in other technology-based assessments that helped to assess the outcome of learning and to diagnose and modify the conditions of learning and instruction (Pellegrino & Quellmalz, 2010; Salend, 2009). This integration can help educators assess the learning domain and learning process (Kickmeier-Rust, 2018). This feature shows that, unlike traditional assessment, the answers students give to questions in DGBA are not independent of each other (de Klerk & Kato, 2017). This function may relate to incorporating assessment purpose, measured construct, items, task, and scoring procedures (Kuo & Wu, 2013), which can bridge the gaps between students' experiences and knowledge (Wang, 2018).

Dynamic characteristics of DGBA. The dynamic features of DGBA refer to the game elements or the gamification of DGBA. Scrutinizing the various definitions of gamification in the literature on DGBA (Aldemir et al., 2018; Bovermann et al., 2018; McCord et al., 2019; Stanescu et al., 2018; Yildirim, 2017) revealed that there are some common components that researchers used to describe gamification. Accordingly, gamification can be defined by the game elements, game rules, time, aesthetics, and game-thinking that promote users' engagement and motivation in learning or assessment, such as collaborative problem-solving. Thus, the dynamic characteristics of DGBA refer to a series of active and powerful properties and outcomes that are produced by the interactions between all game elements and mechanisms such as points, stages, figures, motion, badges, prizes, progress bars, storyline, animation, and leaderboards (Ahmad, 2020; Aldemir et al., 2018). These mechanisms and elements may be considered influential factors in producing complex game genres (Plass et al., 2015), to maximize the appeal of subject matter (Aldemir et al., 2018), and to increase students' motivation and engagement to continue the process of learning and assessment that embedded in DGBA (Ahmad, 2020).

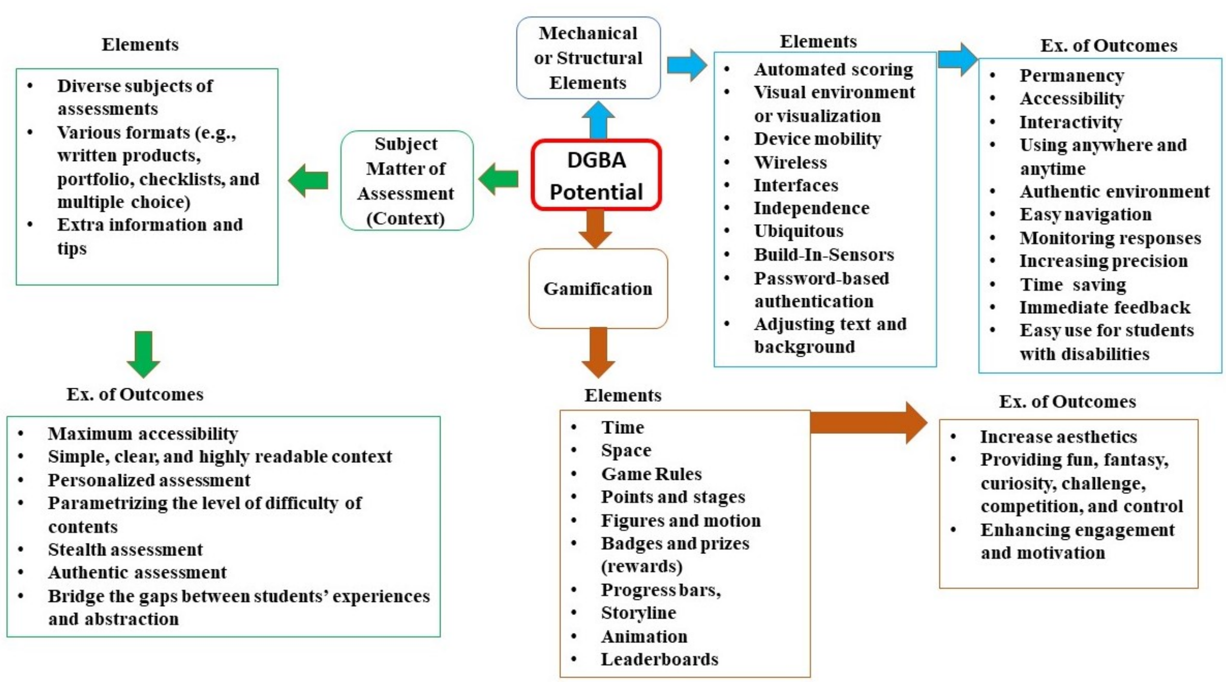
Previous research exemplified some of the dynamic characteristics of DGBA under the name of advantages (Giannakas et al., 2018; McCorda et al., 2019; Turan & Meral, 2018) or core strengths (Kickmeier-Rust, 2018). What Kickmeier-Rust (2018) argued as the prominent features or core strengths of games, such as fun, fantasy, curiosity, challenge, and control, can be considered as the dynamic features of games produced by the above-noted elements or mechanisms. Likewise, generating excitement, energetic pleasure, gratification, and intrinsic motivation are the outcomes of using such elements in gamification. More specifically, Aldemir et al. (2018) believed that motivating and engaging students in thinking to answer questions and solve problems are the dynamic outcomes of gamification. Also, Cirak and Erol (2020) believed that motivation and engagement are two distinguished outcomes of some inherent dynamics of the game, such as imaginary environment, curiosity, competition, and challenges.

E-Learning Industry (2020) specified six dynamic features in the digital game environment that affect students' learning and assessment. These dynamic features create conflict, strategy, chance, aesthetics, theme, and rewards (E-Learning Industry, 2020). In DGBA, a challenge is created by embedding puzzles, hypotheses, or obstacles into the games to be solved by players. Chance is related to multi-layered scenarios or tips that give students a sense of control over the outcome of a game. Aesthetic, which is related to how the overall environment looks, can increase the visual appeal of a game to enhance students' interests. Ahmad (2020) explained that game aesthetic refers to sensory stimuli, uncertainty, interaction, sounds, and the visualization of games that make the game context attractive for students. The theme, in both non-educational and educational digital games, provides players with an understanding of the storyline and the context of games. Objective animations or characters, plots, tension, and resolution are four elements through which a theme is created in digital games (E-Learning Industry, 2020). Finally, Rewards refer to any badge, scores, or verbal incentives that motivate students to engage and continue the game.

Generally, the three aspects of DGBA (mechanical, content or assessment, and gamification) have diverse elements that are considered game influencers, which determine the structural, contextual, and dynamic characteristics of DGBA. All these aspects and influencers define the potential of DGBA in an integrated format. The aspects, their features, and the beneficial outcomes are summarized in Figure 3. The DGBA potential can create an authentic learning or assessment environment that will increase students' engagement, motivation, achievement, enjoyment, and course satisfaction (Al-Azawei et al., 2019; Aldemir et al., 2018; Alexiou & Schippers, 2018; Bovermann et al., 2018; Dondlinger, 2007; McCord et al., 2019; Shute et al., 2016; Wang, 2018). Also, these elements and mechanisms provide a productive capacity to use DGBA in other areas to diagnose mental disorders, treat mental problems, increase subjective well-being, and enhance decision-making (Namli & Demir, 2020) and interpersonal skills (Camilleri & Camilleri, 2017).

Figure 3

A Conceptual Map Linking the Potentials of the Digital Game-Based Assessment



Note. This figure shows elements of three characteristics of DGBA and their example of outcomes.

Using the above-noted elements and the properties of digital games, the Evidence-Centered Design was used as a framework to design, construct, and implement digital game-based assessment (Shute et al., 2016). This framework uses three integrated models, including the task, evidence, and competency models, to build a DGBA. The competency model focuses on personal knowledge, skills, experiences, and other learner attributes, such as collaborative problem-solving. These attributes may consist of unidimensional or multidimensional constructs that aim to be learned or assessed. The task model recognizes those aspects of tasks (contexts) that provide observable evidence for a specific competency (e.g., problem-solving or leadership). The evidence model works as a bridge between the above-noted models. Through this model, the evidence will be derived from the task model to determine the target competency.

Evidence-centred Design provides a strategic framework for implementing these models to build a DGBA in practice (e.g., Raging Skies - Chu & Chiang, 2018). However, the way from defining the target competence or construct to translating evidence (educational content) into a game is long and challenging (An & Coa, 2017). To facilitate and optimize DGBA in this process, the assessment of students' attitudes was considered as a method to determine the suitability, pedagogical value, relevance, and authenticity of content knowledge, and is a way to evaluate the level of student engagement in the process of learning and assessment (Bovermann et al., 2018; Hebert & Jenson, 2018; Mavridis et al., 2017; Voulgari & Lavidas, 2020). Thus, the role of attitude in this process is discussed in the following section.

Attitude and Digital Game-Based Assessment

The Nature and Characteristics of Attitude

Historically, since 1993, there have been numerous studies regarding the definition, components, valence, measurement, and applications of attitude in psycho-social and educational situations (Buhagiar & Sammut, 2020; Cacioppo et al., 1997; Schwarz & Bohner, 2001).

In such studies, the attitude has been defined as a psychological construct showing an individual's tendency toward an object (Okanlawon et al., 2017), as an explicit or implicit evaluation of an object of thought (Bohner & Dickel, 2011 cited in Kolek & Sisler, 2017), and as a cognitive, emotional, and behavioural reaction an individual has toward any object, subject, event, or fact (Aydin, 2012 cited in Han & Carpenter, 2014; Haddock & Maio, 2008). The components, valence (direction) and the strength of attitude toward an object, should be characterized to have an apparent description of attitude.

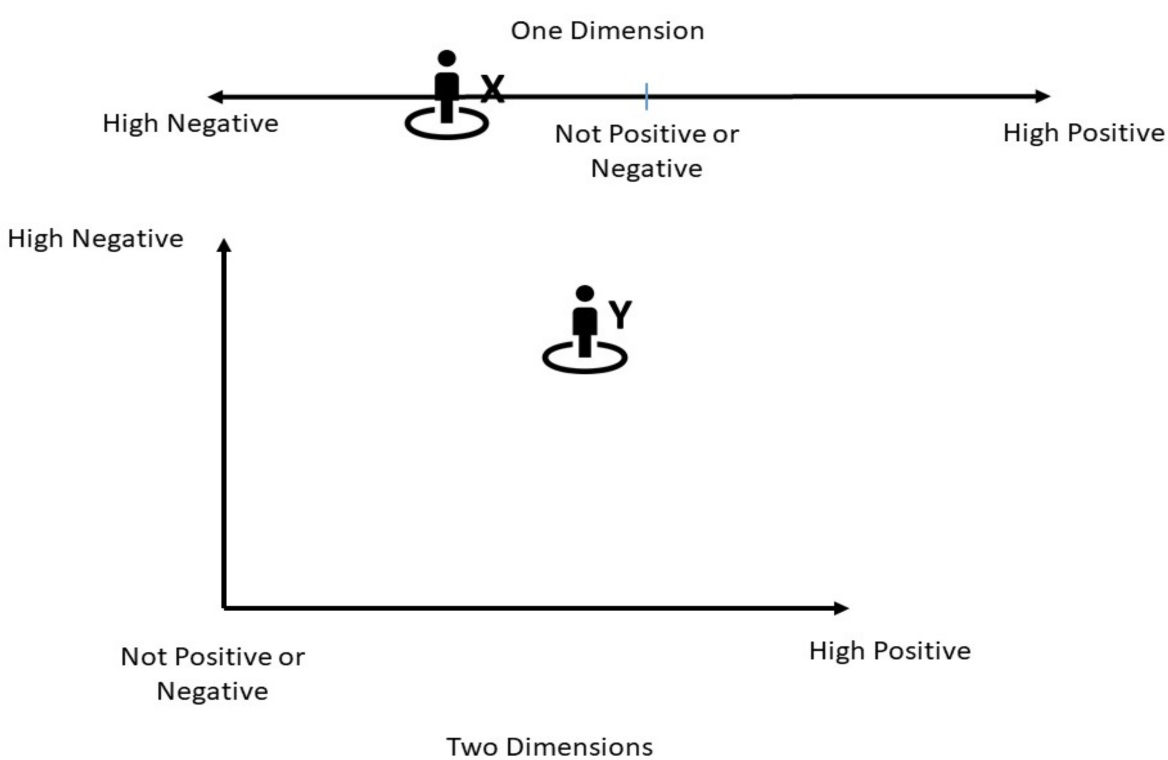
The attitude was argued to have three structural parts or components, including cognitive, emotional, and behavioural constituents (Breckler, 1984; Haddock & Maio, 2008; Ibuot, 2020; Leon-Mantero et al., 2020). The cognitive component of an attitude refers to individuals' specific beliefs, knowledge, attributes, and perceptions about an object (Garcia-Santillan et al., 2012; Liu, 2020; Marti-Parreño et al., 2018). The affective component is related to the degree to which an individual likes or dislikes their object of thought (Liu, 2020; Reich-Stiebert et al., 2019), and the behavioural constituent, which is sometimes called conative, refers to purposeful action or behavioural intention toward an object that is usually shown by supportive actions, verbal statements, approaching toward the object or avoiding from an object (Lee et al., 2019; Liu, 2020; Reich-Stiebert et al., 2019).

These components can differ regarding attitude valence (positions) and strength (certainty). The valence refers to the attitude direction (e.g., positive, negative, and neutral), usually called a capacity of favorability. The strength (certainty) is related to the degree to which an attitude toward an object is strong (Haddock & Maio, 2008), implying that the more robust the attitude, the more stable the attitude. However, there are different perspectives on attitude valence (positions).

One- and Two-Dimensional Perspective. Some researchers posited one- and two-dimensional perspectives that recognize positive and negative elements as stored along a single or separate dimension (Figure 4 - Haddock & Maio, 2008; Reich-Stiebert et al., 2019).

Figure 4

One- and Two-Dimensional Perspectives of Attitude Valence



Note. Adapted from Haddock & Maio, 2008

Several researchers used this perspective implicitly or explicitly to examine teachers' or students' attitudes toward the elements of DGBA or a subject matter (e.g., mathematics) before and after using a DGBA (Grady et al., 2013; Marti-Parreno et al., 2018; Mavridis et al., 2017; Sanchez-Mena et al., 2019). For example, after using computer games, Cankaya and Karamete (2009) examined 176 students' attitudes toward mathematics and educational computer games. They demonstrated that computer games could positively increase students' attitudes toward mathematics and educational games. Likewise, Arias (2014) reported that using video games increased students' positive attitudes toward math and their performance.

Also, Kreutzer and Bowers (2015) used video games in clinical practice to examine their effects on the treatment and the attitude of patients toward such novel approaches. After using the game "Walk in My Shoes" in the process of treatment of patients with post-traumatic stress disorder (PTSD), they reported that self-efficacy video games could not only increase patients' attitudes toward such an approach but also the video game could maximize the treatment effectiveness.

Sanchez-Mena et al. (2019) focused on two factors, perceived usefulness and perceived ease of use. They used a single-dimensional perspective to examine teachers' attitudes toward using digital games in education. After examining 312 teachers' attitudes toward using digital games in education, they found that the perceived usefulness directly influenced teachers' intentional behaviour to use digital games in their instructional program (Sanchez-Mena et al., 2019). In their view, perceived usefulness was the extent to which a person believes using a particular system can improve their job performance. Perceived ease of use is the extent to which a person believes that using a specific system could be free of physical and mental effort (Davis, 1985, cited in Sanchez-Mena et al., 2019).

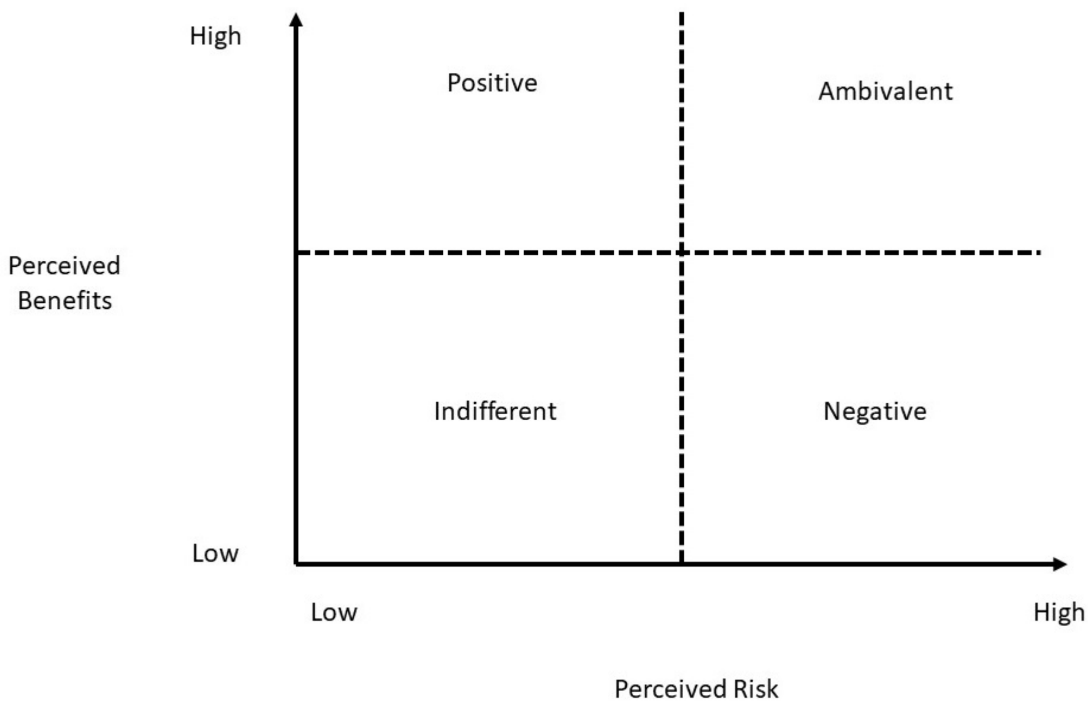
Four-way Typology Model of Attitude. In another perspective of attitude's valence (positions) (Liu, 2020; Poortinga & Pidgeon, 2006; Reich-Stiebert et al., 2019), the one- and two- dimensional perspective was criticized as traditional and oversimplified. Such perspectives cannot identify the nuanced and sophisticated forms of attitude (such as ambivalent and indifferent opinions). The conventional attitude view is also considered a bipolar conceptualization that can distinguish people's positive attitude (perceived benefit) from their negative attitude (perceived risks). However, this approach does not simultaneously clarify individuals' other positions, such as high benefits and risk beliefs that characterize ambivalent attitudes.

Poortinga and Pidgeon (2006) argued that this bipolar conceptualization might simplify the differences between positive and negative groups. Still, this view has difficulty distinguishing such groups from those in the middle (ambivalent and indifferent groups). Accordingly, Poortinga and Pidgeon (2006) introduced a four-way typology model of attitude to reduce such disparities (Figures 6 and 7).

The four-way typology model of attitude (Figure 5) characterizes the individuals' attitudinal positions as positive (perceived benefit), negative (perceived risk), indifferent, and ambivalent (Liu, 2020; Poortinga & Pidgeon, 2006; Reich-Stiebert et al., 2019). As Figure 5 shows, in this model, a combination of perceived high benefit and low risk reflects a positive attitude; a combination of low benefit and high risk reflects a negative attitude; people simultaneously holding high benefit and risk beliefs have an ambivalent attitude, and low scores on both dimensions reflect an indifferent attitude.

Figure 5

A Four-Way Typology of Attitude



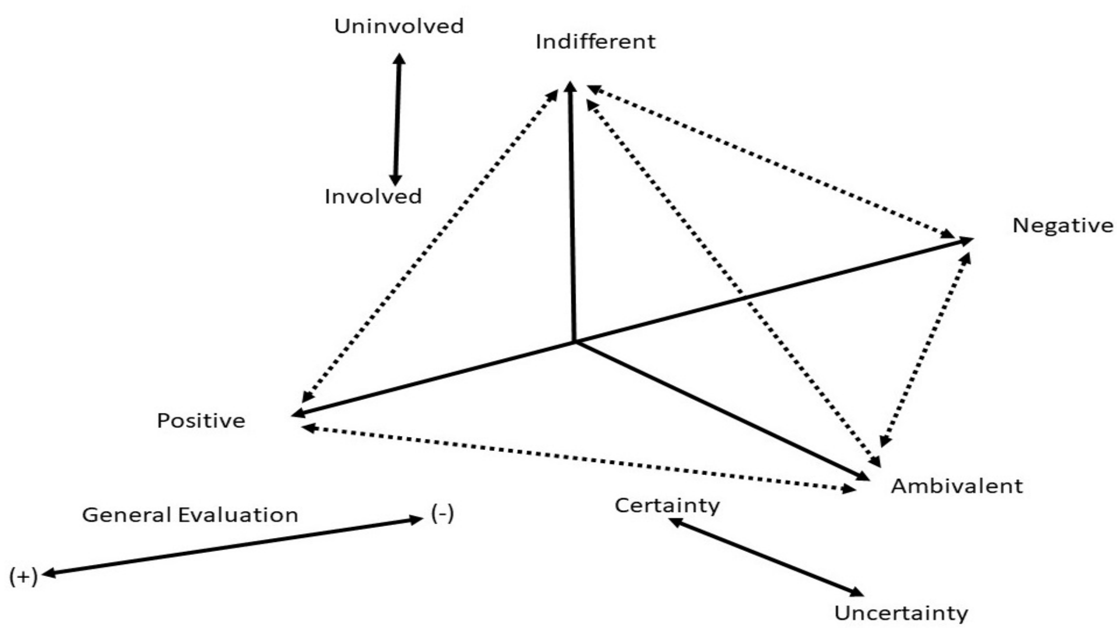
Note. Adapted from Poortinga & Pidgeon, 2006 and Liu, 2020

Since the differentiation between ambivalent and indifferent attitudes was difficult, Poortinga and Pidgeon (2006) used two other components, including interest/involvement and attitudinal certainty, to clearly distinguish four attitudinal positions from each other (Figure 6). Poortinga and Pidgeon (2006) argued that these two dimensions could clarify the positions of ambivalent and indifferent attitudes. Of these dimensions, involvement has the primary role of protecting and maintaining someone's attitude toward an object (Petty & Cacioppo, 1986 as cited in Poortinga & Pidgeon 2006) since the involvement dimension can differentiate between the indifferent attitude on the one hand, and the positive, negative, and ambivalent views on the other hand (Figure 6). This differentiating role of involvement comes from the idea that the positive and negative groups are usually more involved in an issue.

In Poortinga's (2006) model, the dimension of attitudinal certainty is defined as a subjective sense of confidence (conviction) or the accuracy (validity) of one's attitude toward something. Attitudinal certainty, the opposite of ambivalence, helps distinguish the ambivalent attitude from all other attitudinal views (Figure 6). Ambivalent attitude describes the degree to which a person holds both positive and negative feelings or beliefs (attitude) toward an object (see Figure 6 - Conner and Sparks, 2002 as cited in Liu, 2020).

Figure 6

Relationships Between the Four-Way Typology of Attitude in an Attitudinal Space



Note. Adapted from Liu, 2020 and Poortinga & Pidgeon, 2006. This figure shows four dimensions of attitudinal positions, and it also shows to distinguish ambivalent and indifferent positions, two certainty and involvement components can help.

Reviewing the current studies of individuals' attitudes toward new technology revealed that individuals may have an ambivalent or indifferent attitude toward new and emerging technologies [such as DGBL or DGBA], but such types of attitudes are often neglected (Seidl et al., 2013; Snyder & Tormala, 2017). More specifically, since TBL, TBA, DGBL, and DGBA are relatively new multi-technological tools used in educational settings, students may have any of these four-way typological (attitudinal) positions.

Evaluating the Effectiveness of DGBA Through Attitude Assessment

Using the bipolar conceptualization of attitude and experimental methodology, most previous research pursued different goals in studying digital educational games in teaching, learning, and assessment. Examples of various goals include enhancing students' cognitive competencies (e.g., mathematics – Cankaya & Karamete, 2009), increasing self-efficacy or psychological well-being (Bovermann et al., 2018; Kreutzer & Bowers, 2015), optimizing built-in-assessment systems (Hebert & Jenson, 2018) or game-based students response system (Turan, & Meral, 2018), optimizing students' attitude toward educational courses (e.g., math - Mavridis et al., 2017; Van Eck, 2006) or specific subject matters (e.g., geographic location - Hebert & Jenson, 2018), improving students' academic performance (Demirbilek & Tamer, 2010), enhancing motivation (Vankus, 2021), and reducing test anxiety (Van Eck, 2006).

For example, Cankaya & Karamete (2009) studied 176 students' attitudes toward mathematics after using educational computer games (ECG- as a treatment) and found that their attitudes became more positive after using ECG. Likewise, Demirbilek and Tamer (2010) demonstrated that students believed computer games could develop their math vocabulary and concepts. In one study, through attitude assessment and experimental methods, Grady et al. (2013) used three different computer games to assess students' performance in advanced psychiatric pharmacy courses. They concluded that using computer games adjunct to traditional methods is more effective than using them separately.

Using an experimental design with randomized treatment and control groups, Mavridis et al. (2017) compared the effects of online flexible educational games on students' attitudes towards mathematics with traditional procedures in solving mathematical problems. After 14 weeks of treatment, they found that the game method was more effective in improving students' attitudes toward math and enhancing learning math than traditional methods. Moreover, Mavridis et al. (2017) argued that digital games could change students' attitudes and result in significant advantages, such as increasing motivation, making math exciting and accessible, facilitating math understanding, and reducing math anxiety and negative perceptions of math. Through the same methodology, Van Eck (2006) studied the effects of simulation games with pedagogical agents on 123 students' attitudes toward mathematics and found that simulation games increased their positive attitude toward math and improved their performance by reducing math anxiety. Also, Yildirim (2017) examined the effectiveness of gamification on students' attitudes toward mathematics and their performance through an experimental design and found that both attitude and math performance was positively enhanced by using gamification. Likewise, Camilleri and Camilleri (2017) reported that students believed the digital game promoted their interpersonal and social skills, critical thinking, and problem-solving skills.

Apart from the above-noted studies in which attitude assessment was used to examine the effectiveness of digital educational games in students' competencies, some researchers argued that attitude assessment should be used to provide objective evidence and insights about games' elements, dynamics, and narratives with pedagogical interventions or educational subject matters (Aldemir et al., 2018; Kickmeier-Rust, 2018). Aldemir et al. (2018) argued that students' perceptions or attitudes could help designers develop and implement game elements from students' perspectives. Aldemir et al. (2018) analyzed students' attitudes toward game elements to examine how game elements should be designed and implemented from students' views. They found that students' perceptions provided vital insights about nine parts of games, including challenge, narrative, leaderboard, reward, badge, teams, win-state, points, and constraints.

For example, Aldemir et al. (2018) found that challenges (such as questions in DGBA) should not be tough since they could reduce the students' motive to continue the game, and narrative should be embedded in a game to make the content authentic and understandable. Likewise, Marti-Parreno et al. (2018) reported a need to understand *how* and *when* digital games work well in the classroom. For this understanding, attitude assessment is an effective procedure. Using *Kahoot* as a game-based learning and assessment platform, Turan and Meral (2018) examined students' attitudes toward Game-Based Student Response Systems. They found that students' attitudes toward the elements applied in digital games on this platform were positive and such games effectively reduced their test anxiety (Turan & Meral, 2018).

Although these studies through different experimental designs showed that digital educational games effectively enhance students' various competencies, several related studies have some disparities or gaps, as discussed next.

Gaps and Disparities in Previous Studies

Scant Attention to the Tripartite System of Attitude. The literature review revealed that researchers used simplified methods to study individuals' preferences or attitudes toward non-educational and educational-digital games. They rarely focused on three major components of attitude, including "affective," "cognitive," and "behavioural" constituents. Tatli (2018) examined 464 school-age participants to examine their digital game negative or positive preferences. Regarding Lichtenstein and Slovic's (2006) definition of preference, as an individual's attitude towards a set of objects usually reflected in an obvious decision-making process, Tatli's (2018) research gave an informative but simple conclusion about how students perceived digital games. This perception is bipolar (positive or negative).

Similarly, Voulgari and Lavidas (2020) examined the digital game preferences of 274 university students. They realized that students preferred fewer digital games related to science fiction, and 47% of participants had a positive attitude toward using digital games in education. Also, Sanchez-Mena et al. (2019) used a simple method to examine 312 higher education teachers' attitudes toward using educational games and reported their positive or negative aspects. Whereas the above studies are informative, some researchers emphasized that examining different facets of attitude or preferences can provide educational policymakers and teachers with valuable information to optimize DGBL or DGBA in educational settings (Aldemir et al., 2018; Plass et al., 2015).

Scant Attention to Relationships Between the Components of Attitude. In addition to the need for more attention to the components (tripartite system) of attitude in previous studies, the interrelationships among those components were not examined. Kruglanski et al. (2018) argued that although individuals' attitude toward a topic should help researchers predict their behaviours, the process and the conditions through which a cognitive part is translated into behaviour is not fully understood. Based on Kruglanski et al.'s (2018) view, the attitude was considered a cognitive evaluation of an object without considering the other constituents. However, as Kruglanski et al. (2018) argued, studying the interrelationship between such components and influencing factors, such as game experiences, was not thoroughly conducted. Examining the possible relationships can help researchers predict behaviour (Kruglanski et al., 2018), understand the influencing conditions that facilitate translating cognitive evaluation (attitude) into behaviour (Kruglanski et al., 2015), and examine the persistence of attitude toward an object (Kolek & Sisler, 2017). The persistence or strength of attitude refers to the stability of attitude over time and across various situations (Kolek & Sister, 2017). Nevertheless, such relationships between these components of attitude regarding DGBA were not studied previously.

Lack of Attention to Attitudinal Positions. Scrutinizing previous studies showed that one or two attitudinal positions (positive or perceived benefits and negative or perceived risks - Figure 4) were the predominant perspective in the evaluation of students' attitudes toward educational and noneducational digital games (Grady et al., 2013; Marti-Parreno et al., 2018; Mavridis et al., 2017; Sanchez-Mena et al., 2019). Based on this perspective, students' attitude was reported as either a positive or negative valence without paying attention to those with ambivalent or indifferent attitudes (Figure 6).

Accordingly, the four-way typology model (Poortinga & Pidgeon, 2006; Liu, 2020 - Figures 6 and 7) concerning the above-noted components will be used in the current research to elaborate on students' different attitudinal positions toward DGBA. The present thesis research also focuses on the interrelationships among attitudinal positions and tripartite (affective, cognitive, and behavioural) components of attitude toward DGBA.

Scant Attention to Other Influential Factors. Students' and teachers' attitude toward using digital games in education was found to be associated with several factors, such as game and computer experiences (An & Cao, 2017; Marti-Parreno et al., 2018), time and media affinity (Argasinski & Węgrzyn, 2019), age (Camilleri & Camilleri, 2017), position in social strata (Camilleri & Camilleri, 2017), parents' attitude (Kordaki & Gousiou, 2017), game elements (An & Cao, 2017), freedom of choice (Cirak & Erol, 2020), and motivation (Argasinski & Węgrzyn, 2019). These factors were separately investigated in the above-noted studies. For example, Marti-Parreno et al. (2018) studied media affinity, perceived confidence and relevance, and self-efficacy as the significant factors influencing students' attitudes toward using electronic (digital) games in education. They found that perceived relevance had sufficient power to affect students' positive attitudes toward using educational digital games. Also, An and Cao (2017) focused on teachers' experiences. They reported that those with experience designing and using digital games showed a positive attitude toward using them in education compared to those without such experiences.

Some other researchers focused on the interaction between these factors that may influence individuals' attitudes. For example, Argasinski and Węgrzyn (2019) argued that the extent to which users become able to interact with the game's elements (such as challenging questions in DGBA), their motivation and positive attitude would increase. Cirak and Erol (2020) relate users' motivation and positive attitude to the degree to which such games provide users with pleasure and enjoyment. They claimed that fun and entertainment depend on the freedom of choice in playing games.

Apart from that, researchers mainly focused on noneducational games, the factors of pleasure and enjoyment were not studied concerning the influence of other factors, such as the degree of challenges and freedom of choice. Additionally, since challenges in digital games may depend on how well the educational content has translated into a digital game (An & Cao, 2017), it is necessary to examine the interrelationships between these factors. Moreover, because such translations are complex and sometimes are called a problem of the representation of reality in educational simulations (Pohl et al., 2009), it is crucial to use students' attitudes to examine the interrelationships among those factors. As Aldemir et al. (2018) suggested, game designers make and implement game elements from students' perspectives; this research will focus on the interaction between such factors based on the multi-dimensional perspective of attitude.

Purpose of Study

The main scope of the present research is to address facets not currently dealt with in the literature and to reduce the above-noted gaps or disparities regarding students' attitudes toward DGBA. To accomplish this primary purpose, the study was targeted to 1) study the components of students' attitudes toward DGBA and the relationships among those components based on the tripartite system of attitude, 2) use the four-way typology and attitudinal space model to assess the students' attitudinal positions, and 3) examine the effectiveness of the digital educational game in improving students' attitudes toward educational subject matter (e.g., math – *GSI*). These purposes were achieved by exploring and examining the following research questions.

Research Questions

The following research questions were addressed in the current study:

1. What are students’ attitudes toward DGBA in terms of the tripartite - cognitive, affective, and behavioural - system of attitude before and after using a DGBA?
2. What are students’ attitudes toward DGBA in terms of the four-way typology and attitudinal space model?
3. Is DGBA effective in improving students’ academic performance (Knowledge of GSI) and their general attitudes toward DGBA?

Chapter III: Method

This chapter presents the targeted population and sampling method, measures, research design and procedure, the method of data analysis, and ethical considerations. Through these sections, the strategies for conducting experimental treatment and reducing possible errors (e.g., bias errors, measurement errors, experimental errors, and confounding errors) were discussed.

Participants and Sampling Method

Based on a quasi-experimental design, two samples of students aged 19 to 30 attending Islamic Azad University, Tehran Central Branch (IAU-TCB), participated in this study. The overall sample size was 482 students. The samples were recruited after receiving ethics approval from the Research Ethics Board at the University of Alberta.

The sample of students who participated in this study was a convenience sample because all participants came from one university and were non-random. However, several stages were applied to select participants to minimize any sampling contaminations or errors, including (a) identifying a list of all on-campus statistics and research methods classes, (b) selecting several classes randomly, (c) contacting the professors to obtain permission for using their classes, (d) setting up experimental and control groups randomly, (e) defining and describing the goals of research to the samples and emphasizing confidentiality of answers and explaining the ethical issues to potential participants, including they were not required to participate in this study or answer all the questions and also could withdraw at any time, and (f) administrating the study based on the research design. In this stage, pre-test, both groups of participants answered the scale of prior-statistical knowledge of GSI and the digital game attitude scales, and the game of GSI was shared with the Experimental group. The University of Colorado Boulder (2021) has created a new digital educational game called GSI that helps students grasp the statistical concept of graphing slopes and intercepts in the subject of regression. After completing the treatment (GSI) by the Experimental group, both groups participated in the post-test stage and responded to all questionnaires.

Measures

Author-Developed Research Questionnaire

To assess some of the research variables, such as game experiences, socio-demographic features of participants, and game engagement, a questionnaire (Appendix 1) was designed through the review of the literature (Chang et al., 2014; Cutumisu et al., 2019; Namli & Demir, 2020), based on Dawson's (2002) criteria. The questionnaire includes two sections: Section one consists of five questions that assess socio-demographic variables such as gender, age, discipline, marital status, and others. These questions are nominal or ordinal scales. Section two comprises five questions that examine the participants' digital game experiences and engagement. These questions were adapted from different resources using a five-point Likert-type scale from one (*very little*) to five (*a lot*). Of these questions, one was derived from Gameful Experience Questionnaire (Högberg et al., 2019), one item from Game Engagement Questionnaire (Brockmyer et al., 2009), one question from the Attitude Position Scale developed by Liu (2020), and two questions from Attitudinal Position Scale that were developed by Poortinga & Pidgeon (2006).

Knowledge and Skill Acquisition

To assess the knowledge and skill acquisition of the participants, the researcher used the Scale of Prior-Statistical Knowledge (University of Colorado Boulder, 2021).

The Scale of Prior-Statistical Knowledge. In line with the digital simulation of Graphing Slope-Intercept (GSI), the participants' knowledge of line equations and drawing slope-intercept were assessed using eight questions. These questions were introduced by PhET (Physics Education Technology- University of Colorado Boulder, 2021). They were adapted for this study by three experts in statistics who have been teaching statistics at universities. To provide the validity of questions, the experts were asked anonymously to rate the suitability of the questions based on the digital game of *GSI* and the criteria of statistical courses for undergraduate students in social science. Each question was rated between 87% to 95% suitability (Appendix 2). The internal reliability value of the Prior-Statistical Knowledge Scale was α = .80, showing reasonable consistency.

Digital Gaming Attitude Scale (DGAS)

Initially, the scale was introduced by Hazar and Demir in 2018 to assess teachers' and students' attitudes toward using a game in their classes. DGAS was revised and developed by Demir and Bozkurt (2019) to measure university students' attitudes toward digital gaming. The 18 scale questions examine three cognitive, affective, and behavioural components of attitude (five items for cognitive, five items for affective, and eight items for behavioural components based on the tripartite system of attitude). Each question is ranged on a five-point Likert scale from one (*strongly disagree*) to five (*strongly agree*). These questions were derived from 43 items after using exploratory factor analysis (Demir & Bozkurt, 2019). Some examples of 18 items of DGAS include "I think the benefits of digital games are questionable" (cognitive), "I do not enjoy playing digital games" (affective), and "I keep playing digital games until I pass all levels" (behavioural). In the final version of DGAS, items 2, 3, 5, 6, 7, 10, and 18 are scored reversely (Appendix 4).

The confirmatory analysis revealed that the 18-item version is valid and reliable (Namli & Demir, 2020). In both studies, Demir and Bozkurt's (2019) and Namli and Demir's (2020), the internal consistency of the scale was reasonable using coefficient alpha (.78 for the Cognitive subscale, .71 for the Affective subscale, and .86 for the Behavioural subscale). Demir and Bozkurt (2019) used the split-half method to measure the reliability of all subscales. They determined the correlation between both parts of subscales between .77 and .84. The developers of the scale suggested rating the level of students' attitude based on scores as 1-18 (very low), 19-37 (low), 38-54 (moderate), 55-72 (high), and 73- 90 (very high). The 18-item version of DGAS was used in this study through translation and back translation by two expert reviewers who are fluently trilingual in English, Turkish, and Persian. The internal reliability of the DGAS was calculated in the present study (coefficient alpha = .91). Additionally, three components of DGAS, Cognitive, Affective, and Behavioral, were also evaluated using the same method, yielding scores of .722, .82, and .889, respectively.

Computer Game Attitude Scale (CGAS)

The CGAS measured players' attitudes toward computer gaming (Chappell & Taylor, 1997). The original scale measured two constructs, including *comfort* and *liking*. Initially, the scale was revised in 2013 by adding new items to measure these two highly reliable constructs (Liu et al., 2013). This version consisted of 60 items. Conducting new studies on CGAS, Chang et al. (2014) attempted to revise the scale for Canadian participants in different school levels (e.g., 2nd-grade students and others). In their revision, the scale was reduced to 17 items with a five-point Likert option that is scored from one (*strongly disagree)* to five *(strongly agree)*, designed to measure three components affective, cognitive, and behavioural.

Some examples of 17 items in this scale include: "Using computer games in school is a good way to learn" (cognitive), "I am very interested in solving quests/questions/missions in computer games" (affective), and "I talk about computer games with my friends" (behavioural). The scale's internal consistency through Cronbach Alpha was .89 (Chang et al., 2014).

Also, the internal consistency value for each subscale was between .70 and .93. The correlations between subscales were between .50 and .69, which is low enough to be separated from each other and not overlap, showing a good correlation to maintain total internal consistency. Recently, the scale's reliability was examined through a study on game-based learning, and results suggested acceptable correlations between CGAS and the questionnaire of the Technology Acceptance Model (Chen et al., 2017). Before analyzing the data, the internal consistency of the CGAS in the current research was calculated using Cronbach's Alpha with the result of $\alpha = .951$. Similarly, the internal consistency of Cognitive, Affective, and Behavioral components was also assessed before analyzing the data using the same method, yielding scores of .89, .89, and .91, respectively. In addition, given that the CGAS has not been previously validated using empirical data, a validation study was conducted to collect different types of reliability and validity evidence using Cronbach alpha, confirmatory factor analysis and Pearson correlations. Thus, three types of validities were examined in the next part: construct, convergent, and internal.

Construct Validity. To test the factorial structure of the CGAS, confirmatory factor analysis (CFA) was carried out. The analyses were conducted using SPSS-26 and Mplus 8.3. First, model fit indexes were examined to ensure the data fit well.

Model Fit Indexes. Since the CGAS item response format was five-ordered categories, and due to less normality in the data, the robust maximum likelihood (ML) estimator, the

Satorra–Bentler correction, was used for the parameter estimation in CFA. This method was implemented in Mplus 8.3 via the estimator MLM. Also, comparative-fit index (CFI), Tucker and Lewis Index (TLI), Chi-Square, root mean square error of approximation (RMSEA, which estimates lack of model fit and compensates for model complexity), and standardized root mean square residual (SRMR; Joreskog and Sorbom, 1984 cited in Barbaranelli et al., 2014) were used to assesses the discrepancy between observed and predicted covariances (see Table A in Appendix 10). Regarding Chi-Square, the current study revealed that it was significant ($p < .05$; Table A in Appendix 10). Even though a desired result is non-significant, Meyers et al. (2006) stated that Chi-Square should not be considered the only value in judging the overall fit of the model because it is sensitive to sample size. This was previously stated by Jöreskog and Sörbom (1982). Thus, the other indices were examined too. Based on the criterion Kline (2011) discussed, the values of CFI and TLI between .90 to .95 are acceptable. In the present study, CFI (.90), TLI (.83), and RMSEA was .1. Also, SRMR (.07) was smaller than .08 (Table A in Appendix 10). In addition, based on the Hoelter index for the sample size adequacy, to acquire the desired Chi-Square at the significant level of .05 should be n=168. The number of samples in the present research was 482, which was big enough. In conclusion, based on CFI and SRMR and Hoelter index (n=168), the model represents an acceptable to moderate fit to the data (Hu & Bentler, 1999).

CFA Model. All items have been loaded onto three factors (Figure A in Appendix 10). The standardized coefficients for the Behavioral component ranged from .402 to .90; for the Cognitive component, they were .63 to .82; and for the Affective component, they ranged from .80 to .87. Considering that they were all statistically significant, this indicates that all items had a significant impact on their respective factors and were well-structured in three components of Behavioural, Cognitive and Affective, as expected.

Convergent and Internal Validity Evidence for CGAS. Convergent and internal validity of CGAS were explored with Pearson moment-to-moment correlations. The correlations between the three components and the entire scale were calculated to assess how the different parts of the CGAS scale measure one entity and how they correlate (Table C in Appendix 10). The cognitive, affective, and behavioural components are highly associated with the entire scale, with coefficients of .915, .937, and .896, respectively, showing a high level of internal validity in the scale of CGAS.

Furthermore, the CGAS and DGAS instruments are assumed to measure the same construct. Therefore, the correlation coefficient of both scales ($r = .806$, $p < .001$) can serve as a convergent validity for both.

Attitudinal Position on Digital Game (APDG)

The scale of APDG is an adapted questionnaire that was prepared based on two scales developed by Poortinga and Pidgeon (2006) and Liu (2020). Both scales were based on the four-way typology and attitudinal space model (see Figures 6 and 7 - Poortinga & Pidgeon, 2006; Liu, 2020; Reich-Stieberta et al., 2019).

The scale developed by Poortinga and Pidgeon (2006) consists of 10 statements, nine for general attitudes toward the benefit and the risk of using genetically modified food and one direct question with four options to measure attitudinal positions including “positive,” “negative,” “ambivalent,” and “indifferent” (interest/involvement). The questions were designed based on the Likert scale ranging from one (*totally disagree*) to five (*totally agree*). After using principal components analysis (PCA), the nine-item questionnaire was loaded with two components: perceived benefits (positive attitude) and perceived risk (negative attitude). Both components were internally consistent with Cronbach's alpha of .80 and .81. In addition to one direct question for the assessment of attitudinal positions (indifferent and ambivalent), Poortinga and Pidgeon (2006) used five questions to assess indifferent (interest/involvement) position and three questions to assess "attitudinal certainty" (Figure 6) with high internal consistency. Also, they used discriminant analysis to describe the differences between groups identified by the direct measure for the model of four-way attitude typology.

The scale that Liu (2020) developed to assess the attitudinal position of self-driving vehicles was also based on the model of the four-way attitude typology. Liu's (2020) scale, a revised and adapted version of Poortinga and Pidgeon's (2006) scale, consists of 15 questions to assess the general and specific perceived benefit and general and specific perceived risk. Also, he used one direct question introduced by Poortinga and Pidgeon (2006) to differentiate four attitudinal positions. Additionally, Liu (2020) demonstrated that two other dimensions, including "behavioural intention" and "willingness to pay," could differentiate four attitudinal positions from each other. These two dimensions were assessed by four questions (Liu, 2020).

Moreover, Liu used a formula of Ambivalence = $(P + N)/2 - | P - N|$ to verify and distinguish the ambivalent position from the other positions. In his formula, P denotes the mean of two perceived general benefit items, and N represents the mean of two perceived general risk items. Using Cronbach's Alpha, Liu's (2020) scale was internally consistent for all subscales over .80.

In the current study and through using and adapting the above-noted scales, the scale of APDG (Appendix 6) was designed based on the model of four-way attitude typology (Poortinga

& Pidgeon, 2006; Liu, 2020; Reich-Stieberta et al., 2019). The APDG has two versions; one assesses participants' general attitudinal positions on the digital game, and the other for evaluating participants' specific attitudinal positions on the game of *GSI*.

The second version was used after conducting the experimental treatment. Each version consists of twenty-eight questions based on a five-point Likert scale. The items are scored from one (*strongly disagree)* to five *(strongly agree)*. Of these 28 questions, 20 items were derived and adapted from Liu's (2020) study and one question from Poortinga and Pidgeon's (2006) study that was also used by Liu (2020). As well five questions were adapted from Poortinga and Pidgeon's (2006) examination to assess "attitudinal certainty" and "interest/involvement."

Additionally, two multiple-choice questions were added to assess the elements of digital game-based assessment (Figure 3). These questions examined the main aspects of DGBA, *mechanical, gamification,* and *content facets.* The APDG's internal reliability was calculated, and the coefficient alpha was .88.

Research Design

Two methods were used in this research to answer the research questions. A survey method was used. As well, to examine the effectiveness of using the digital game on students' attitudes and their knowledge and skill acquisition, a pre-and post-test design with two groups of classes, one for control and the other for treatment, was used in this study. After selecting the group of classes, the research was done based on the following pre-and post-test design.

Group one is an Experimental group assigned to receive treatment (GSI). This group was tested before and after completing the experimental treatment. Group two, as a Control group, was not assigned any treatment but was tested in pre and post-test. This design allowed the researcher to compare the groups to determine the effects of experimental treatment on students' knowledge and skill acquisition, attitude components, and the four attitudinal positions. However, because of non-randomization, the researcher focused on selecting groups from different university departments to ensure minimal treatment contamination. Also, all groups were unaware of each other during the experiment to reduce the risk of experimental errors. Since the experiment was performed once (one-shot treatment), the mortality, maturation, and history threats were minimized not to violate the research validity.

After receiving ethics approval from the University of Alberta Research Ethics Board, the Ethics of IAU-CTB, and permission from the supervisory committee, four classes (groups of students with the appropriate requirements) were selected from the university to experiment. The course instructors were contacted for permission to perform the experiment and to administrate the treatment and the surveys based on the defined stages in Table 2. If no permission was given instructor, another class was replaced until the experiment was completed.

Table 2

Executive Stages of Experimental Treatment of GSI for Experimental Groups

Stages	Sessions[1]	Descriptions	Remarks
Stage 1: Classical teaching of GSI	One session	Teaching the topic of statistical regression and *Graphing Slope-Intercept*	One week interval between stage 1 and 2
Stage 2: Administrating the treatment	One session	Step 1: Introducing the game of GSI. Step 2: Administering pre-tests Step 3: Setting computer systems to access the GSI. Step 4: Conducting the training part for 15 minutes. Step 5: Conducting the assessment part of GSI. Step 6: Collecting the data of step 5.	

Step 7:	Administering post-test and collecting data

Note. [1] The time for each session is one and a half hours

Based on Table 2, students in each group were informed and assured that the experiment and the information provided on their questionnaire were confidential, that no identifying information was required, and that only the researcher had access to the data. Participants were informed that all questionnaires would be destroyed after coding data and entering them into a password-protected computer. Students were allowed to ask questions. After conducting the experiment and survey, students were thanked for their cooperation and participation. They also were reminded to keep the cover letters to contact the researcher for a summary of the results or any further questions. The experimental treatment is described next.

Experimental Treatment

The digital game of GSI was employed in this study. It is a novel digital educational game developed by the University of Colorado Boulder (2021) to help students understand the statistical concept of graphing the slope(s) and intercept in the subject matter of regression. A remarkable number of students in social sciences at universities have difficulties understanding statistical concepts (such as variance and regression) that affect their attitudes toward math and statistics as well as their academic performance negatively (Firoozabadi et al., 2015; Kazemi & Fatemi, 2010; Rekabdar & Solaymani, 2008).

Some of these difficulties were demonstrated as errors in understanding statistical concepts and questions, processing skills, and using notations (Kurniawan & Wahyuningsih, 2018). To reduce such challenges, the positive effects of digital educational (statistical or mathematical) games were demonstrated by researchers (Cankaya & Karamete, 2009; Mahmoudi et al., 2015; Saffari, 2016a, 2016b). In her study, Saffari (2016a) demonstrated that digital educational games could improve students' skills in statistics and math. Hung et al. (2014) also showed that students' math performance was enhanced by using digital games. However, the efficacy of GSI has not been examined previously.

Digital Game of Graphing Slope-Intercept (GSI)

The Physics Education Technology (PhET) Department at the University of Colorado Boulder designed and constructed the Graphing Slope- Intercept digital game. The game covers two math and statistics topics: Slope-Intercept Form and Graphing Line Equations. These topics are taught in statistics and mathematics courses at both high schools and universities.

The PhET established five significant goals for this game program: (a) Graphing a line given an equation in slope-intercept form, (b) identifying the slope and y-intercept of a line given its graph or equation, (c) writing an equation in slope-intercept form given a graphed line, (d) predicting how changing the values in a linear equation will affect the graphed line, and (e) predicting how changing the graphed line will affect the equation. The game was developed into two parts to approach these goals: the " training" and the "assessment." Built-in a hands-on atmosphere, the first part is a self-learning section through which students can learn slope-intercept by changing the line position, manipulating the slope and y-intercept in the equation, and watching the results. In this learning atmosphere, students explore the slope-intercept form of a line and connect the slope and y-intercept to the line equation; they do not need to listen to any lecture or narrator (Figures 7 and 8).

Figure 7

GSI Home Page

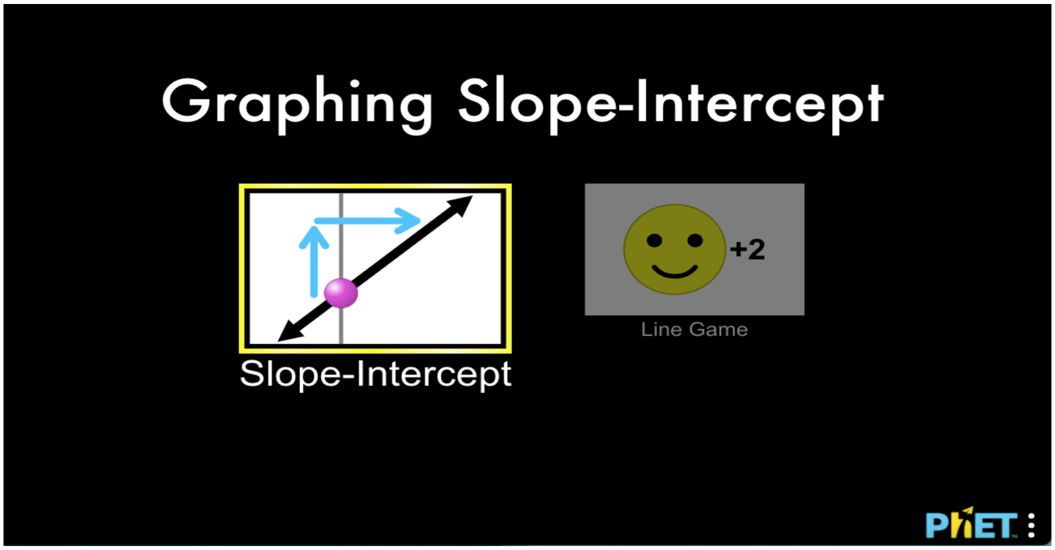
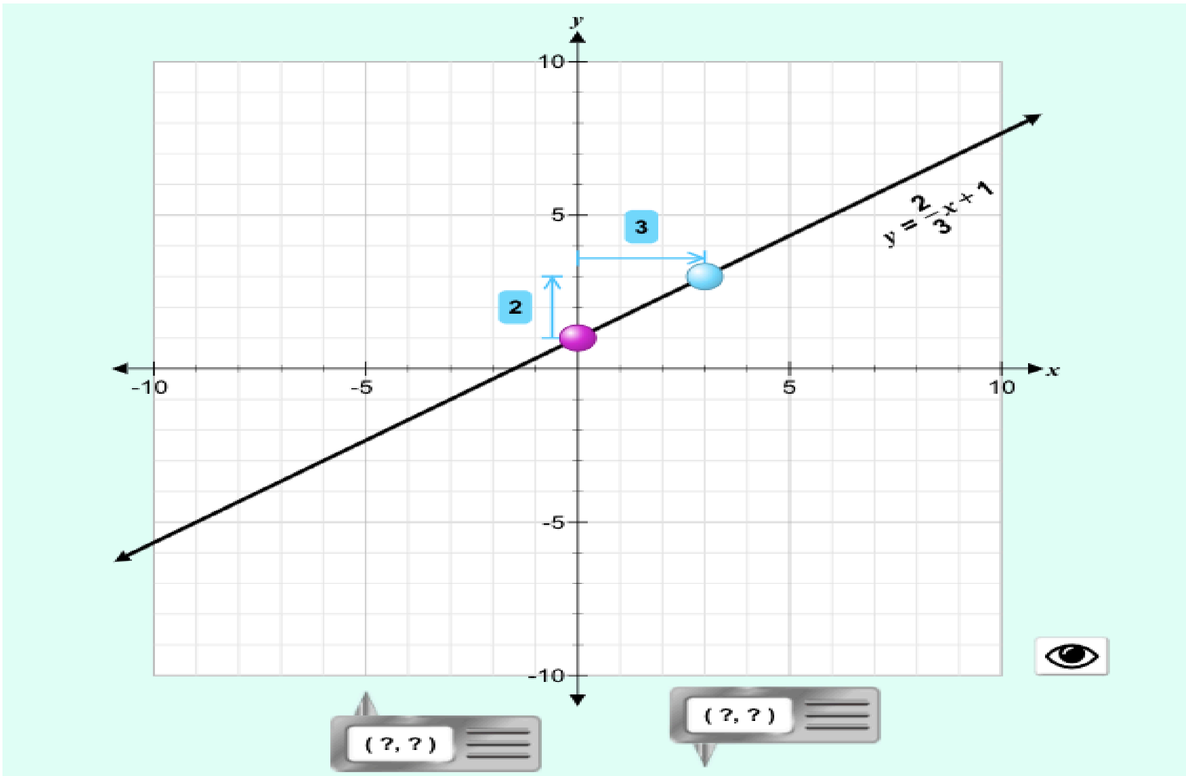


Figure 8

GSI Training Page



In the training section, some tools include saving lines, accessing reference lines of y = x or y = -x, and the point tool to get the integer coordinates of any point (Figure 9). These tools help students to compare multiple lines simultaneously (Figure 10).

Figure 9

Tools in GSI

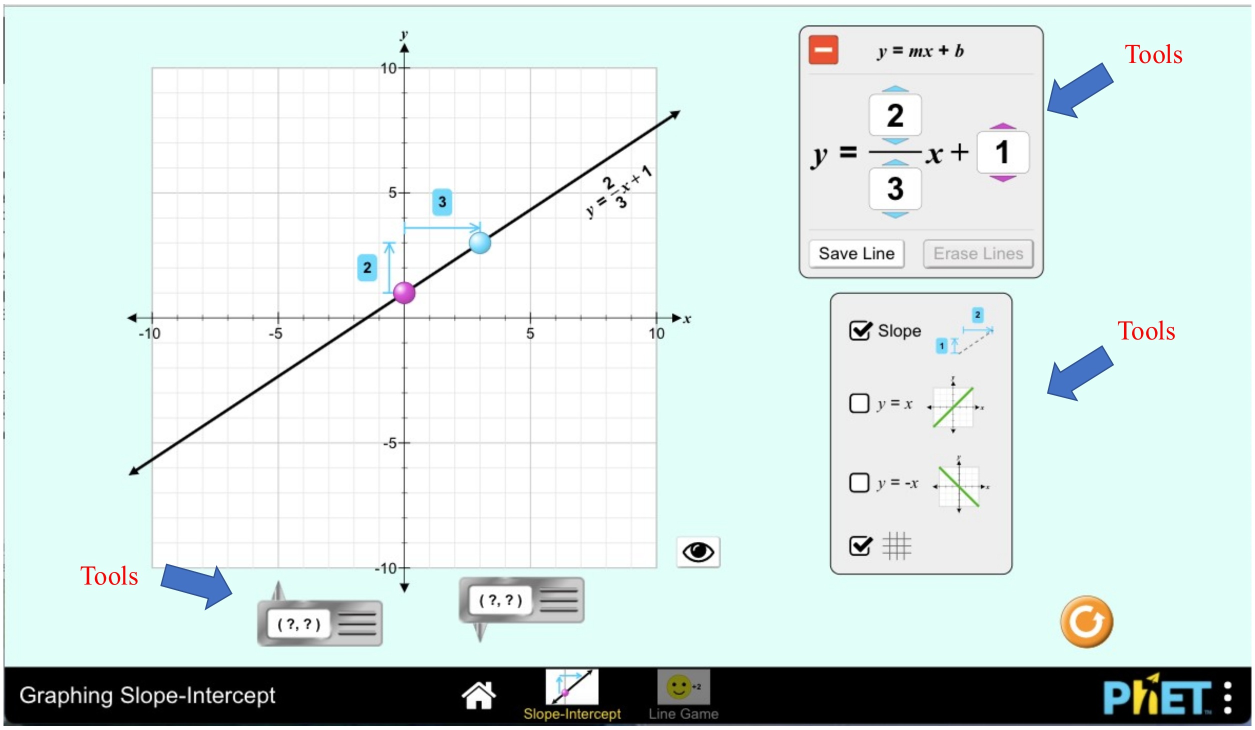
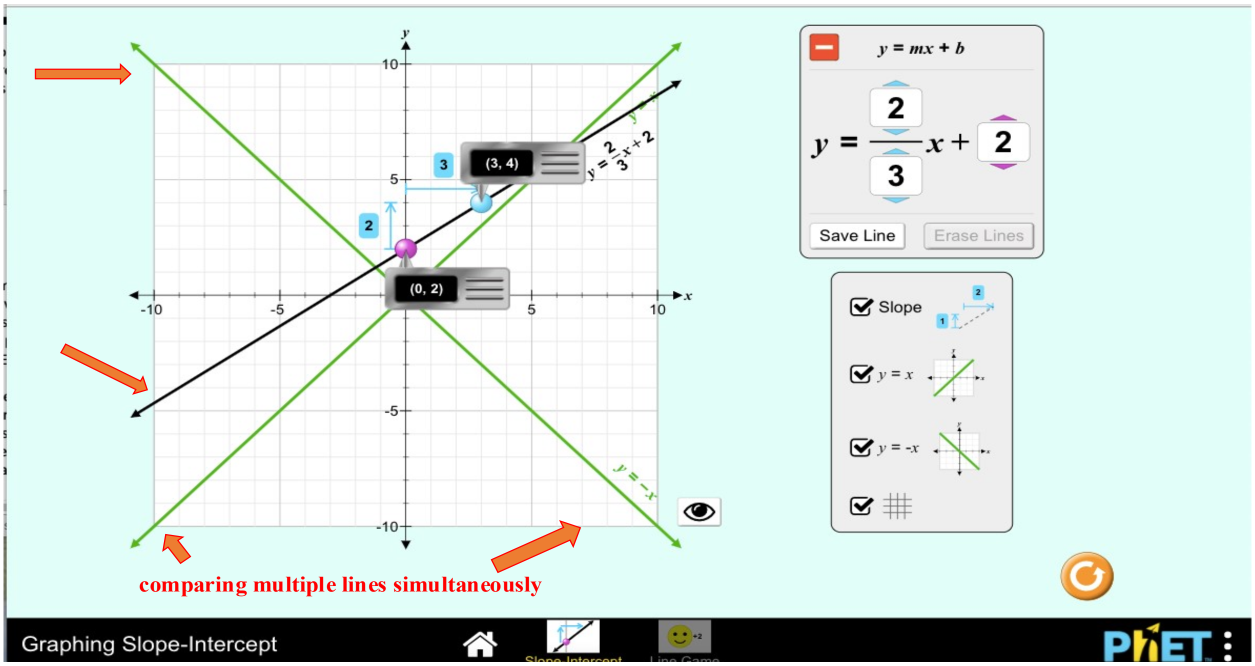


Figure 10

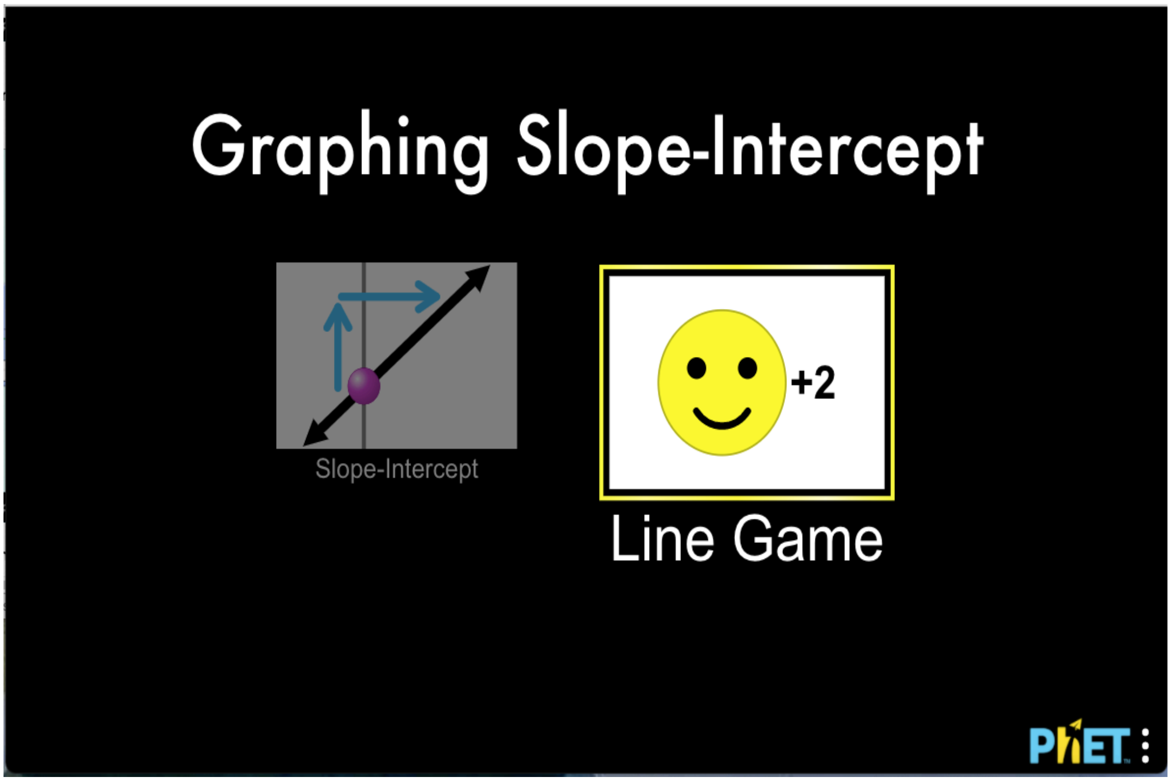
Comparing Multiple Lines Simultaneously



Since the training is not limited, students may spend as much time as needed. After feeling mastery of the content, they can go through the practice and assessment called "Line Game" (Figure 11).

Figure 11

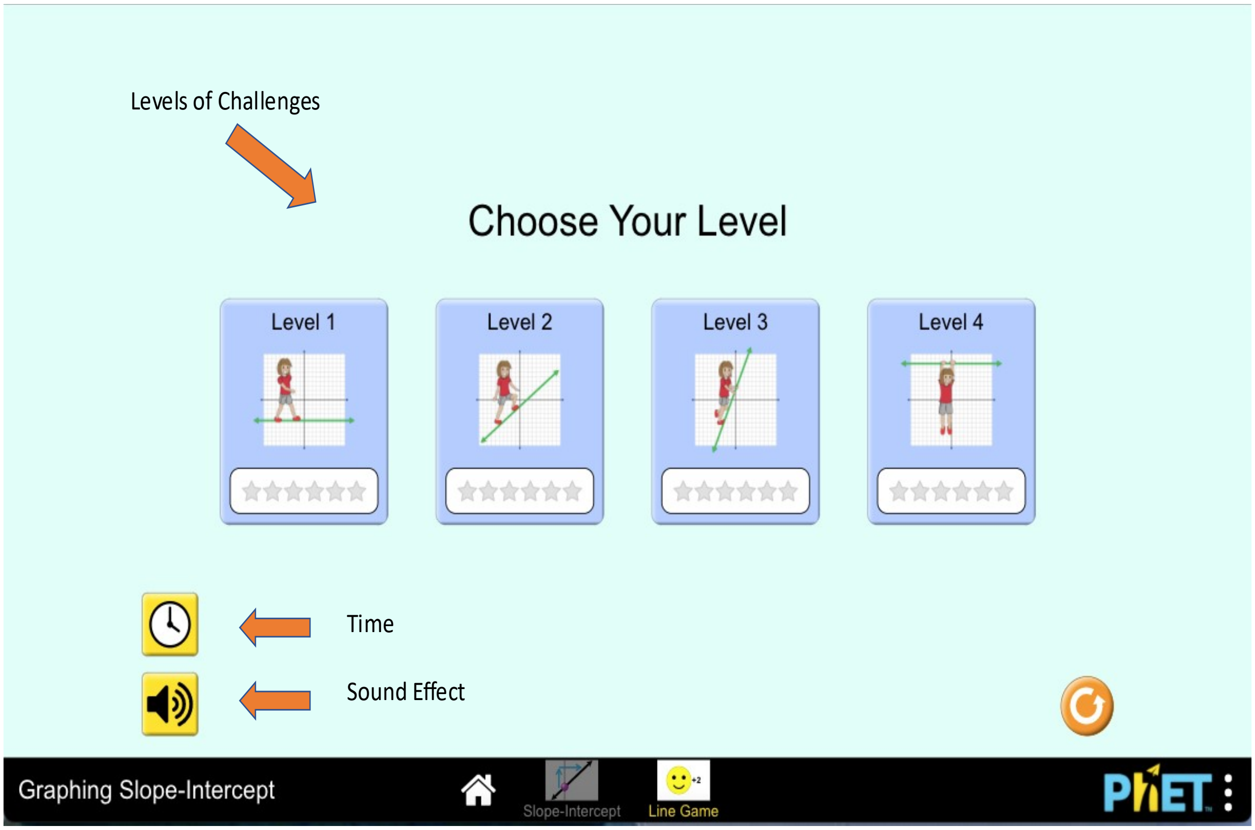
The Assessment Part of GSI (Line Game)



The Line Game has 24 challenges (questions) in four levels (Figure 12). There is a timer that students or teachers can use freely since it is optional. Also, there is a sound effect to reward and increase the game's attractiveness, which could be muted or unmuted.

Figure 12

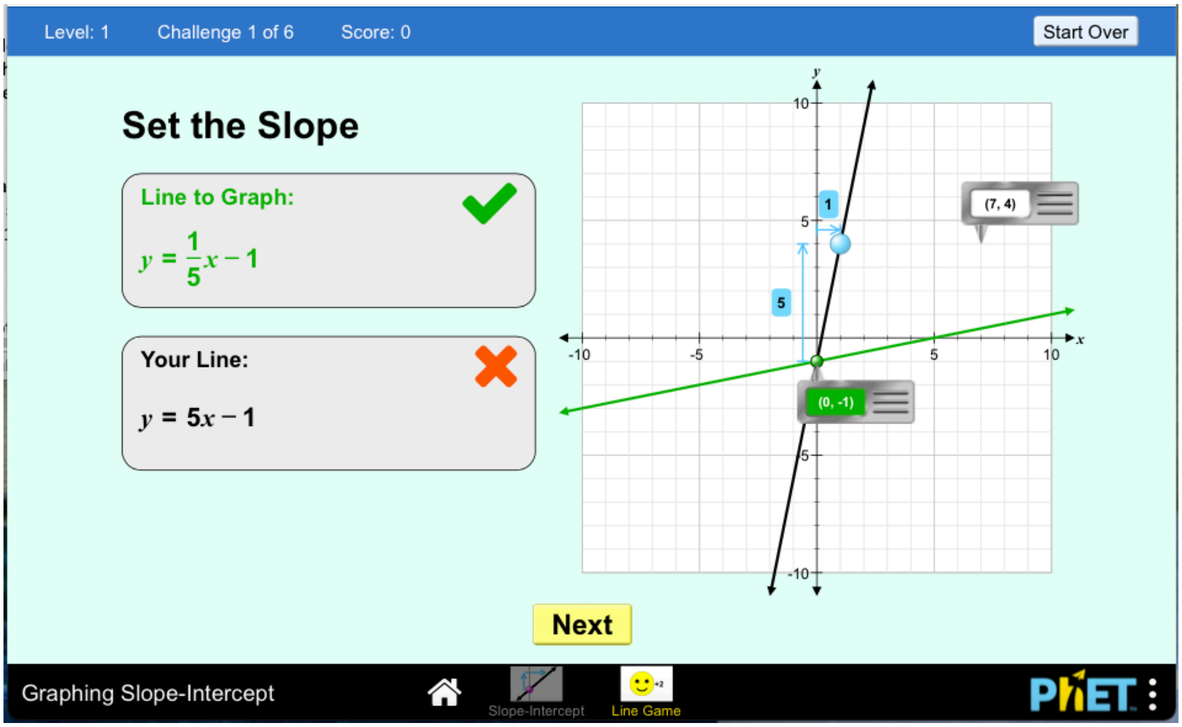
Assessment Part of GSI in Different Levels



In levels one and two, students set the slope or Y-intercept by manipulating the equation or the graph. In levels three and four, they make the equation, draw a diagram of the line, or put points on the line (Figure 13).

Figure 13

Making Equations and Lines in GSI

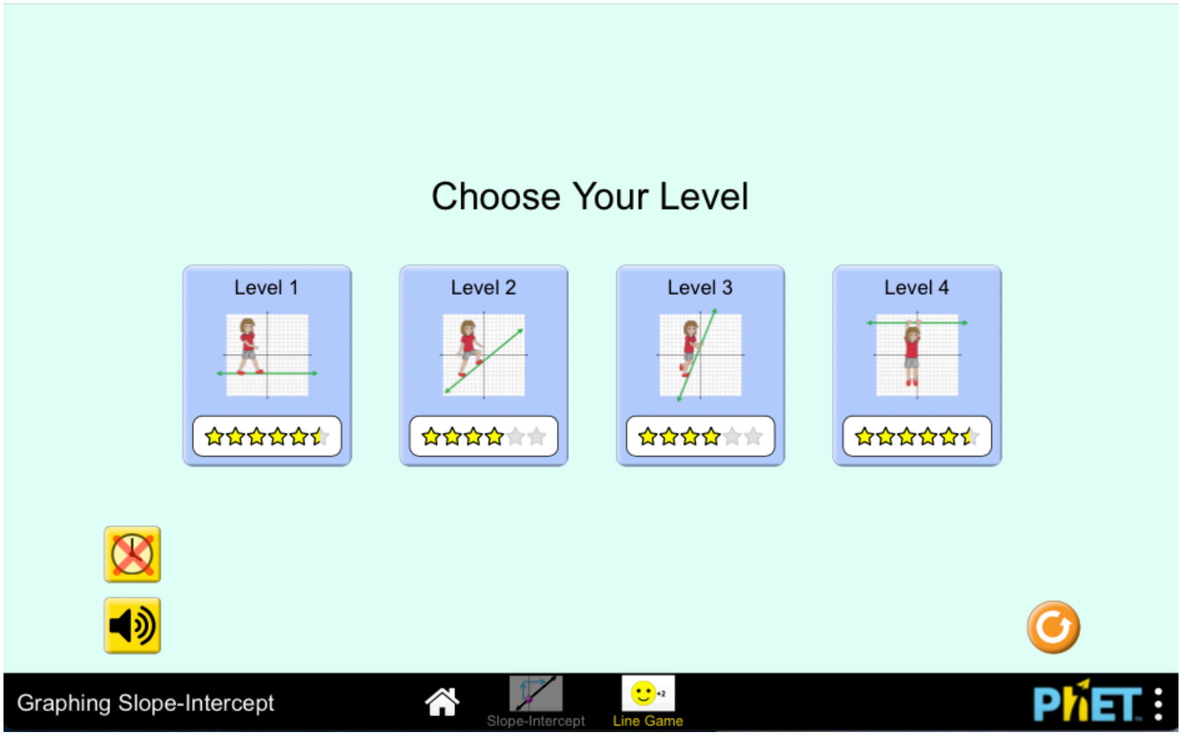


Each challenge can be solved in one or two attempts. If the students can solve the challenge on the first attempt, they will get two points; if they do on the second attempt, they will get one point, otherwise zero.

The range of scores for each level is from zero to 12, and for the overall levels is from zero to 48. The game shows stars to students as their scores on the game. Each full star represents two points, and half of a star represents one point. For instance, for a hypothetical student (Figure 14), the total score in level one is 11; in level two, it is eight; for level three, it is eight; for level four is 11, and the total score is the sum of these levels which is 38.

Figure 14

Scoring in GSI



Students have the option to select the start level of assessment too. Thus, they can skip one or two levels. However, they should continue when they start a level and cannot skip the following levels. Unlike the training section, there is a clock in the assessment part that students can activate to show the minutes and seconds of the assessment.

Data Analysis

In the data analysis process, descriptive analysis was first conducted to explore data (e.g., missing data), analyze the primary assumptions of inferential statistics, and provide insight into possible measurement errors. Then, based on the research questions, the following statistical procedures were used.

To assess and differentiate four groups of attitudinal positions and the levels of attitude components based on the tripartite system and the four-way typology and attitudinal space model, *t*-tests, MANOVA, MANCOVA, and regression analysis were used. These tests, examined the research questions: Q1 (*What are students' attitudes toward DGBA based on the tripartite (cognitive, affective, and behavioural) attitude system before and after using a DGBA (GSI)?*); Q2 *(What are the students' attitudes toward DGBA based on the four-way typology and attitudinal space model?); and* Q3 *(Is DGBA effective in improving students' knowledge and skill acquisition (Knowledge of Graphing-slop Intercept) and their general attitudes toward DGBA (e.g., GSI)?)***.** The researcher needed to examine initial participant differences, as they were not entirely randomly assigned. This involved identifying variables that may naturally differ between the groups before treatment and using them as potential covariates. Additionally, to examine the validity of the CGAS scale, confirmatory factor analysis (CFA) was conducted, too.

Ethical Considerations

The Tri-Council Policy Statement

Ethical Conduct for Research Involving Humans (TCPS2), which is a joint policy of Canada's three federal research agencies (the Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Social Sciences and Humanities Research Council of Canada (SSHRC) or 'the Agencies') defined research as "an undertaking intended to extend knowledge through a disciplined inquiry and systematic investigation" (CIHR., NSERC., & SSHRC, 2014, p. 5). In TCPS2, it was argued that there had been many examples in which the participants of studies have been profoundly harmed by research. To avoid such events, some thoughtful and obligatory ethical principles or articles were established by TCPS for academic and research institutions across Canada.

These ethical principles also make researchers a commitment to respecting and protecting participants, increase the duties of honest and thoughtful inquiries, have rigorous analysis, and commit to disseminating research results. Having such obligations, the current research follows the ethical principles of the University Research Ethics Committee at the University of Alberta. Accordingly, the current study aimed to minimize the following ethical issues:

Personal Information.

1. Participants of this research were students of 19 and over years of age. Participants and their professors were informed verbally and in writing in the cover letter of their rights to decline to answer questions or withdraw from the study without penalty.

2. Personal identifying information was not required on any of the questionnaires. However, each package of questionnaires had a code to track back if participants wanted to withdraw from the research later.

Confidentiality.

3. Efforts were made to protect the confidentiality of participants' responses and written answers to open-ended questions. Although there were some open-ended questions from participants, the researcher could not identify the participants by name on those questions. These questions were coded using a number system to ensure that participant anonymity had been maintained.

Participating Rights.

4. Students were not required to participate in this study or answer all the questions. Also, they were told they could withdraw at any time while completing the measures should they change their mind, and all materials they have achieved until that point will be shredded. If they choose to withdraw later, they can contact the researcher and provide her with the code number on this letter, and all their data can be removed from the computer and shredded hard copies if they are still available. This was mentioned in the verbal instruction and the cover letters.

Possible Harms.

5. There was no physical harm in this research. Also, the potential for emotional harm was minimal. However, being mindful that completing the questionnaires may resurrect some traumatic memories for some students, the cover letter contained contact information for counselling services.

Research Results.

6. After approval from the University Research Ethics Committee at the University of Alberta, questionnaires and experimental treatment were administered.
7. Data from the surveys and the treatment were coded and stored on a secure server at the university. Hard copies of the surveys were shredded once the data was entered. Electronic data files are kept for three years following the thesis defence. Then they will be deleted from the computer to allow time to disseminate the information through conference presentations and published articles.
8. Only statistical data were reported in this thesis research, and only group statistical data will be noted in future presentations or papers.

Chapter IV: Results

Data analyses are presented in two sections. The sample and related variables and their descriptive statistics were introduced in the first part. Second, the research questions were analyzed by using inferential statistics.

Based on the nature of the research questions, correlations, MANOVA, MANCOVA, Confirmatory Factor Analysis (CFA), regression analysis, and some nonparametric procedures were used. SPSS-24th version, Mplus, and Tableau were utilized to conduct these analyses.

Descriptive Statistics

Sample Size

Beshlideh (2012) noted that the number of participants should be at least 15 per variable for linear regression and other statistical procedures in general. Since the analysis of my research questions deals with three to seven main independent and dependent variables, the overall number of participants (*n* = 482) was deemed adequate to perform statistical procedures (Beshlideh, 2012; Hooman, 2010; Krejcie & Morgan, 1970; Weisberg, 2005). Additionally, the researcher calculated the necessary sample size to have enough power in statistical methods to do the analyses by applying the standard formula of $[z^2 * p(1-p)] / e^2 / 1 + [z^2 * p(1-p)] / e^2 * N]$ (Hooman, 2013). where z is the z-score, p is the standard of deviation, N is the population, and e is the margin of error. After applying the formula, it was determined that the required sample size would be 333 for the population of 2504, according to the university registrar's office. Upon comparing it to the current study's sample size of 482, it can be concluded that the sample size is sufficient.

Descriptive Information of Participants and Variables

As Table 4 shows, 62.2% of the participants were between 19 and 20 years old, and 25.5% were between 21 and 23. A smaller portion of students (12%) was over 24 years old. The mean of the participant's age was 21.66, with a standard deviation of 5.66. In terms of sex, about 86% (*n* = 417) of participants were female, and the rest (13.6%, *n* = 65) were male. As Table 4 shows, 274 participants (56.8%) were classified as the middle category of socioeconomic status, and about 35% (*n* = 170) of participants indicated their SES as a Good status. Of 482 participants, 42.7% (*n* = 206) mentioned having somewhat experience in digital games. About 39% categorized themselves as having little or very little experience in digital games, and only 18% of participants have a lot or very much experience in this case. Contrary to the *digital game experience*, most participants admitted they spent little or very little time finding a suitable digital game for themselves (74%, *n* = 368). Participants' satisfaction with playing digital games was also almost spread equally in all categories. Regarding the *amount of time playing the digital game*, the results revealed that most participants played very little to somewhat (92%, *n* = 447), and only about 7% played a lot or very much. Table 5 shows the information on critical variables studied in this study.

Table 4

Participants' Demographic Variables (N = 482)

Demographic Characteristics	*n*	%	Demographic Characteristics	*n*	%
Gender			Digital Game Experience		
Female	417	86.6	Very Little	68	14.1
Male	65	13.5	Little	121	25.1
Age			Somewhat	206	42.7

19 - 20	300	62.2	A Lot	70	14.5
21 - 23	123	25.5	Very Much	17	3.5
> 24	59	12.2	Satisfactory of Playing DG		
SES			Very Little	101	21.0
Very Weak	3	.6	Little	114	23.7
Weak	20	4.1	Somewhat	169	35.1
Middle	274	56.8	A Lot	77	16.0
Good	170	35.3	Very Much	21	4.4
Very Good	15	3.1	Time Spent Finding DGs		
Amount of Playing DG			Very Little	207	42.9
Very Little	161	33.4	Little	161	33.4
Little	157	32.6	Somewhat	105	21.8
Somewhat	129	26.8	A Lot	7	1.5
A Lot	28	5.8	Very Much	2	0.4
Very Much	7	1.5			

Table 5

Descriptive Information for Studied Variables (N = 482)

Variables	mean	SD
Age	21.66	5.66
Attitude score toward DGBA	53.73	12.68
Cognitive Subtest	27.43	5.56
Affective Subtest	12.74	3.57
Behavioural Subtest	13.64	4.75
DGBA Elements Total score	10.43	2.65
Mechanical Elements Subtest	10.46	2.91

Game Elements Subtest	13.15	3.52
Content Elements Subtest	7.69	2.23

Missing Data

The data included the responses of 494 university students. The percentage of total missing data was 2.44%, either due to students' absences (1.02%) in the post-test intervention survey or non-response (1.42%). Three approaches usually address missing data, including replacing missing data with an imputed value, pairwise deletion, and removing the cases. Since the percentage of missing due to non-responding to the post-test (1.02%, n = 5) was small, and the sample size was large enough, removing the cases was used for those who did not answer the whole post-test. Also, since the number of random missing was few (1.42%, n = 8), the replacement of missing data with a "Series of Mean" method was used to solve the problem (Acock, 2005; Gravetter & Wallnau, 2009; Pigott, 2001).

Inferential Statistics

Research Question 1

What are students' attitudes toward DGBA based on the tripartite (cognitive, affective, and behavioural) attitude system before and after using a DGBA (GSI)?

To investigate students' attitudes toward DGBA based on the tripartite system of attitude, students' responses to three subscales in the DGAS, including cognitive (5 items), affective (5 items), and behavioural (8 items), were analyzed. It is worth mentioning that according to Mircioiu and Atkinson (2017), in Likert ordinal data with a high response rate (>15), confining the analysis to non-parametric methods results in loss of information and parametric methods may pave the way for further detailed examinations. As Sulivan and Artino (2013) stated, many educators and researchers create Likert-type items and group them into a survey scale to measure less concrete concepts like trainee motivation, patient satisfaction, and physician confidence. This is recommended because a single survey item may not fully capture the concept being assessed. To ensure the components of the scale are sufficiently intercorrelated and measure the underlying variable, experts suggest using the Cronbach alpha or Kappa test or factor analysis technique (Sulivan & Artino 2013).

Analyses were conducted in three steps. In the first step, the post-test differences between the two (Experimental and Control) groups in each attitude component were examined using a *t*-test (Table 6). The results showed that the differences between the Experimental and Control groups in each of the three components of attitude were significant after using the game of GSI. For *cognitive component* $t(480) = 4.07$, $p < .001$; for *affective component* $t(480) = 3.42$, $p < .001$; and for behavioural *component* $t(480) = 3.037$, $p < .01$. The mean differences between both groups are shown in Table 6.

Table 6

The Differences Between the Experimental and Control Groups in Each of the Three Components of Attitude

	Mean (n)	Standard Deviation	Mean Differences	t (df)	P-value
Cognitive Experimental Group	3.368 (220)	.547	.20567	4.077 (480)	.001
Cognitive Control Group	3.161 (262)	.555			
Affective Experimental Group	3.230 (220)	.720	.24028	3.421 (480)	.001

Affective Control Group	2.989 (262)	.806			
Behavioural Experimental Group	2.852 (220)	.739	.21881	3.037 (480)	.003
Behavioural Control Group	2.633 (262)	.841			

In the second step, the within-group comparisons were made to identify whether there were any differences in tripartite components of attitude in the Experimental group before and after using the treatment (The game of GSI). The results revealed that just the mean difference of the behavioural component in the pre and post-test for the Experimental group was significant, $t(219) = -2.45$, $p < .01$. The within-group comparison of all three components of attitude for the Control group did not show any significant differences between pre and post-test (Table 7). That is, there were no changes in this interval.

Table 7

Pre and Post-t-tests for Experimental and Control Groups in Three Components of Attitude

		Mean (n)	Standard Deviation	Mean Differences	t (df)	P-value
Paired 1	Cognitive Pre-test Experimental Group	3.381 (220)	.507	.0137	.383 (219)	.702
	Cognitive Post-test Experimental Group	3.368 (220)	.547			
Paired 2	Affective Pre-test Experimental Group	3.302 (220)	.731	.0723	1.746 (219)	.082

	Affective Post-test Experimental Group	3.230 (220)	.720			
Paired 3	Behavioural Pre-test Experimental Group	2.750 (220)	.780	-.1031	-2.597 (219)	.010
	Behavioural Post-test Experimental Group	2.852 (220)	.740			
Paired 4	Cognitive Pre-test Control Group	3.200 (262)	.592	.0376	.860 (261)	.390
	Cognitive Post-test Control Group	3.162 (262)	.555			
Paired 5	Affective Pre-test Control Group	3.033 (262)	.852	.0429	.696 (261)	.487
	Affective Pre-test Control Group	2.990 (219)	.806			
Paired 6	Behavioural Pre-test Control Group	2.497 (262)	.848	-.1372	-2.17 (261)	.081
	Behavioural Post-test Control Group	2.634 (262)	.842			

*sig p <.01

Finally, based on the results of the first step, the roles of covariates in the mean differences between the Experimental and Control groups were examined using MANCOVA. Before conducting the MANCOVA, correlations were calculated between three attitude components and four possible covariates, socio-economic status (SES), digital game experience, amount of time spent playing digital games, and prior knowledge in graphing slope-intercept to determine the inclusion of covariates in further analyses. The results let the researcher choose which covariate should be controlled (Table 8).

Table 8

Correlation of the Three Attitude Components and Four Possible Covariates

	Four Possible Covariates				Three Attitude Components		
	Prior Knowledge	SES	DG Experience	Time Spent DG	Cognitive	Affective	Behavioural
Prior Knowledge	1.00						
SES	.031	1.000					
DG Experience	.008	-.048	1.000				
Time Spent DG	.032	-.060	.660**	1.000			
Cognitive	.127	-.067	.413**	.404**	1.000		
Affective	.069	-.103	.482**	.568**	.697**	1.000	
Behavioural	.046	-.056	.441**	.587**	.499**	.707**	1.000

Note. the ** denotes Spearman correlation is statistically significant at the .01 level.

Table 8 shows that two variables of *digital game experience* and *the amount of time spent playing digital games* have significant associations with the three components of attitude. Hence, they were included as covariate variables in analyses.

A repeated-measures factorial mixed design was performed to compare pre and post-tests and also Experimental and Control groups regarding three attitude components while controlling two covariates. The means and standard deviations for the three attitude components are presented in Table 9.

Table 9

Descriptive Statistics for Three Attitude Components

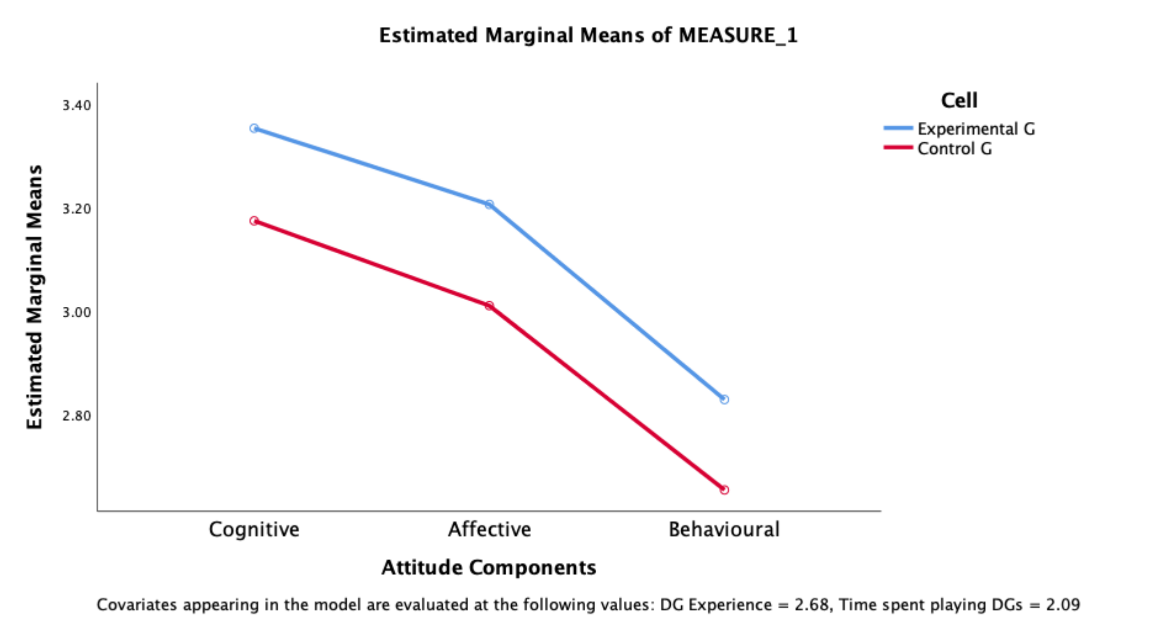
		Mean (n)	Standard Deviation
Cognitive Pre-Test	Experimental Group	3.383 (220)	.507
	Control Group	3.199 (262)	.591
Cognitive Post-Test	Experimental Group	3.368 (220)	.548
	Control Group	3.161 (262)	.555
Affective Pre-Test	Experimental Group	3.304 (220)	.732
	Control Group	3.023 (262)	.852
Affective Post-Test	Experimental Group	3.230 (220)	.721
	Control Group	2.989 (262)	.806
Behavioural Pre-Test	Experimental Group	2.756 (220)	.773
	Control Group	2.496 (262)	.848
Behavioural Post-Test	Experimental Group	2.852 (220)	.741
	Control Group	2.633 (262)	.842

Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 69.01$, p = .001, and therefore degrees of freedom were corrected using Huynh-Feldt estimates of sphericity (ε = .890). Controlling two covariates, results showed that there are significant changes in the main effect of the comparison in attitude components in pre and post-test in experimental and control groups at the p-value of .001 level, F(2, 848.73) = 94.461, p = .001, partial η^2 = .165. Also, the interaction of the three attitude components and pre/post-test was significant at the p-value of .001 level, F(2, 925.13) = 13.194, p = .001, partial η^2 = .027. However, consulting the mean plot revealed that since the lines are almost parallel, the interaction effect is minimal and negligible.

Focusing on the main effect, there was no need to conduct a post hoc analysis since there were just two levels of the between-subject factor. Consulting the means in Table 9 and Figure 15 revealed that the components had higher means in the Experimental group post-test than the Control group.

Figure 15

Marginal Means of Attitude Components in the Experimental and Control Groups



To understand what characteristics of the DGBA (GSI) attracted students' attention and to what degree they can predict participants' attitudes, a regression analysis (stepwise method) was used for the Experimental group in the post-test. Of all characteristics, four elements of DGBA, including game rules, enjoyability, engageability, and understandability of content, could predict about 30% of the variability of the total score of attitudes toward DGBA (Table 10 and Figure 16, A & B; Appendix 11). When using the cognitive component of attitude as the dependent variable, the characteristics of game rules, understandability of content, and increasing motivation could predict 24% of the positive cognitive component of attitude (Figure 16, C & D; Appendix 11). For the affective component, the time of the game and the degree to which the game was relaxing (reducing stress) could predict 22% of the variability (Figure 16, E & F; Appendix 11). For the behavioural component of attitude, two factors, motivating and game relaxing, could predict 13% of the variability (Figure 16, G & H; Appendix 11).

Table 10

The Results of Multiple Regression to Predict the Attitude

Models	**Predictors***	**Unstandardized Beta**	**Standardized Beta**	**R**	**R^2**	**R^2 change**	**F Change**
Model 1	(Constant)	30.66					
	Engageability	7.70	.461	.461	.212	0	58.79***
Model 2	(Constant)	26.96					
	Engageability	4.842	.290	.508	.258	.046	13.43***
	Enjoyability	3.979	.274				
Model 3	(Constant)	23.67					
	Engageability	4.251	.254	.530	.281	.023	6.883**
	Enjoyability	3.579	.247				
	Game Rules	2.373	.162				

Model 4	(Constant)	21.39						
	Engageability	3.155	.189		.543	.295	.013	4.115*
	Enjoyability	2.619	.181					
	Game Rules	2.303	.157					
	Understanding	2.799	.167					

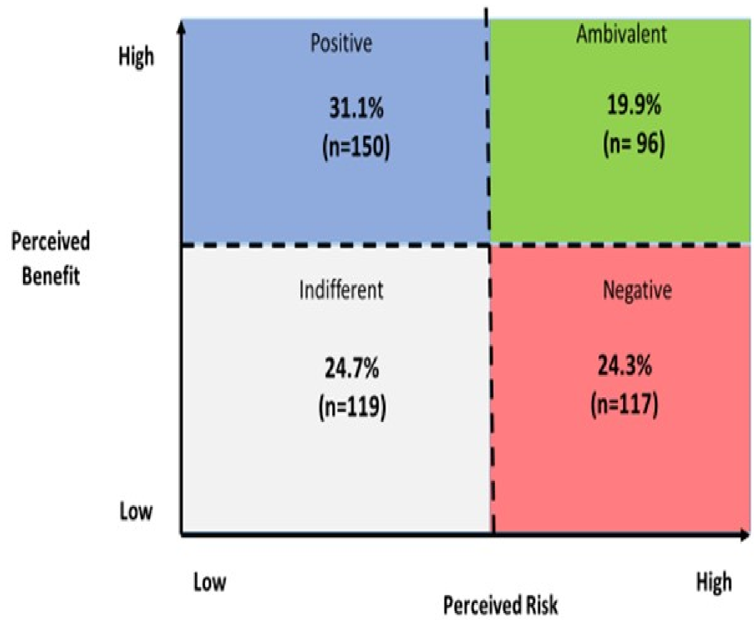
Research Question 2

What are the students' attitudes toward DGBA based on the four-way typology and attitudinal space model?

To answer this question, two steps were taken. First, the percentage of responses in each attitudinal position was calculated for overall samples (Figure 17). Figure 17 illustrates that the highest percentage of participants' responses is 31.1% (n = 150), belonging to the *positive attitudes*. Also, 24.3% (n = 117) of participants had a *negative attitude*, 24.7% (n = 119) had an *indifferent attitude* toward DGBA, and 19.9% (n = 96) of participants had the *ambivalent attitude*, which was the lowest rate amongst the four attitudinal positions.

Figure 17

The Percentage of Students' Attitudes Toward DGBA in Terms of the Four-Way Typology and Attitudinal Space Model



In the second stage, the mean of each attitude component in the pre and post-test within each group of attitudinal position was calculated for both Control (Figure 18) and Experimental groups (Figure 19). This stage explored whether the three components of attitude show significant differences in pre and post-test within each attitudinal position (*ambivalent, indifferent, negative,* and *positive* groups). The results for each group of participants were presented in the following.

Control Group. The results for the *ambivalent* group revealed that there were no significant differences between pre and post-test in all three components of attitude (for affective

$t(108) = 1.33$, $p = .185$; for cognitive $t(108) = 1.80$, $p = .08$; and for behavioural component $t(108) = -.47$, $p = .64$). Also, non-significant results were found for both *indifferent* and *negative* groups. As expected, these results showed that *the ambivalent, indifferent,* and *negative* groups of attitudes had no changes in their three components of attitude from the pre-test to the post-test. However, the positive group showed significant changes from the pre-test to the post-test in both *affective* and *behavioural* components but not in the *cognitive* component. For *affective*, $t(82) = -2.37$, $p < .05$, and for behavioural, $t(82) = -3.06$, $p < 005$ (Table 11).

Table 11

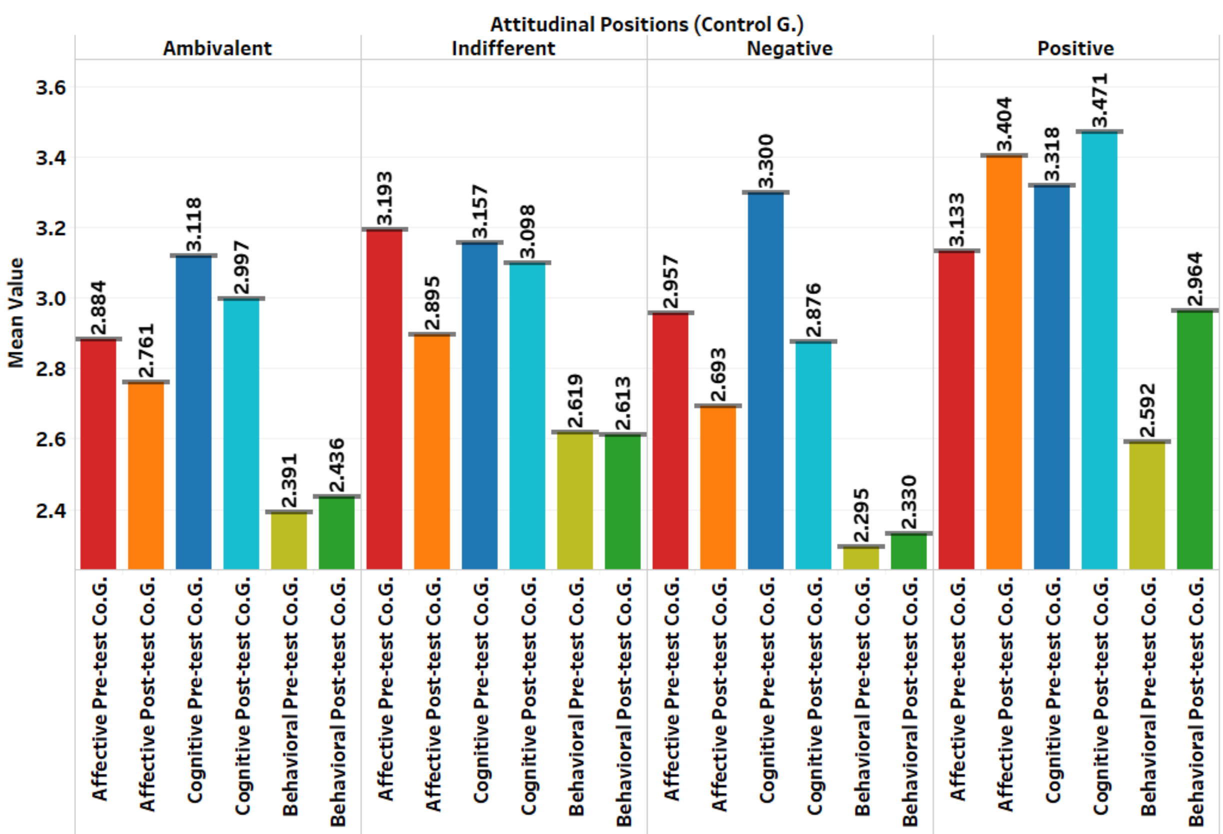
Results of Paired-Sample t-Test for Each Component of Attitude in the Control Group in Terms of Attitudinal Positions

Attitudinal Positions	Attitude Components	N	Mean Difference	SD Difference	t (df)	p-value	Cohen's d Effect Size	Hedges' Adjustment
Ambivalent Group	Affective Pre; Affective Post	109	.12257	.95818	1.336 (108)	.185	.128	.127
	Cognitive Pre; Cognitive Post	109	.12128	.70084	1.807 (108)	.074	.173	.172
	Behavioral Pre; Behavioral Post	109	-.04495	1.00257	-.468 (108)	.641	-.045	-.045
Indifferent	Affective Pre; Affective Post	56	.29821	.95831	2.329 (55)	.024*	.311	.307
	Cognitive Pre; Cognitive Post	56	.05964	.60921	.733 (55)	.467	.098	.097
	Behavioral Pre; Behavioral Post	56	.00661	.91739	.054 (55)	.957	.007	.007
Negative	Affective Pre; Affective Post	14	.26429	.80918	1.222 (13)	.243	.327	.307
	Cognitive Pre; Cognitive Post	14	.42429	.72554	2.188 (13)	.068	.585	.550
	Behavioral Pre; Behavioral Post	14	-.03500	.92814	-.141 (13)	.890	-.038	-.035

Positive	Affective Pre; Affective Post	83	-.27108	1.04316	-2.368 (82)	.020*	-.260	-.257
	Cognitive Pre; Cognitive Post	83	-.15253	.73796	-1.883 (82)	.063	-.207	-.205
	Behavioral Pre; Behavioral Post	83	-.37169	1.10555	-3.063 (82)	.003*	-.336	-.333

Figure 18

The Mean Value Plots of Three Components of Attitude in Pre and Post-Test Based on Attitudinal Positions for the Control Group



Experimental Group. Similar to the Control group, the Paired-Sample *t*-test was used for each attitude component for the Experimental group. The results revealed that in the *ambivalent* group, the difference between the pre-and post-test of the *affective* component was significant t (54) = 1.98, $p < .05$. However, the mean differences of the *cognitive* and *behavioural* components of attitude were not significant in the *ambivalent* group (Table 12). Approximately the same result was found for the *indifferent* and *negative* groups of Experimental. It means that the game of GSI did not change the attitude of *indifferent* and *negative* groups of Experimental. However, the mean differences between the pre and post-test of *cognitive* and *behavioural* attitudes were significant for the *positive* group of Experimental (t (85) = -2.51, $p < .05$ for the *cognitive* component, and t (85) = -3.85, $p < .001$ for the *behavioural* component). These results revealed that the game of GSI could increase the *positive cognitive* and *behavioural* attitude of DGBA in the Experimental group (Figure 19).

Figure 19

The Mean Value Plots of Three Components of Attitude in Pre and Post-Test Based on Attitudinal Positions for the Experimental Group

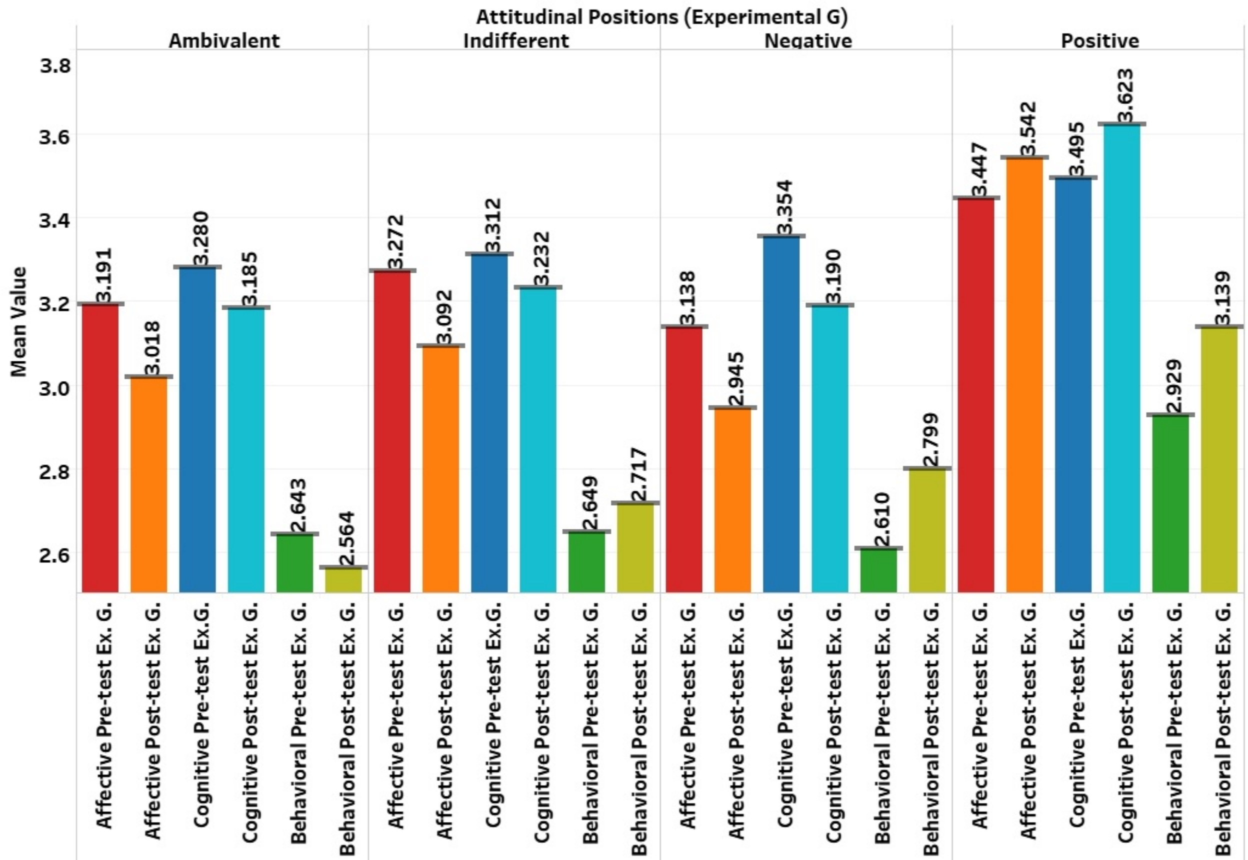


Table 12

Results of Paired-Sample t-Test for Each Component of Attitude in Experimental Group in Terms of Attitudinal Positions

Attitudinal Positions	Attitude Components	N	Mean Difference	SD Difference	*t* (df)	*P*-Value	Cohen's d Effect Size	Hedges' Adjustment
Ambivalent Group	Affective Pre; Affective Post	55	.17309	.64778	1.982 (54)	.053*	.267	.263
	Cognitive Pre; Cognitive Post	55	.09455	.58227	1.204 (54)	.234	.162	.160
	Behavioral Pre; Behavioral Post	55	.07964	.60535	.976 (54)	.334	132	.130
Indifferent	Affective Pre; Affective Post	50	.18000	.61578	2.067 (49)	.044*	.292	.288
	Cognitive Pre; Cognitive Post	50	.08000	.50305	1.125 (49)	.266	.159	.157
	Behavioral Pre; Behavioral Post	50	-.06840	.60323	-.802 (49)	.427	-.113	-.112
Negative	Affective Pre; Affective Post	29	.19310	.65024	1.599 (28)	.121	.297	.289
	Cognitive Pre; Cognitive Post	29	.16414	.56909	1.553 (28)	.132	.288	.281
	Behavioral Pre; Behavioral Post	29	-.18931	.68945	-1.479 (28)	.150	-.275	-.267
Positive	Affective Pre; Affective Post	86	-.09535	.54942	-1.609 (85)	.111	-.174	-.172
	Cognitive Pre; Cognitive Post	86	-.12791	.47220	-2.512 (85)	.014*	-.271	-.268
	Behavioral Pre; Behavioral Post	86	-.21023	.50706	-3.845 (85)	.001*	-.415	-.628

Research Question 3

Is DGBA effective in improving students' knowledge and skill acquisition (Knowledge of Graphing-slop Intercept) and their general attitudes toward DGBA (e.g., GSI)?

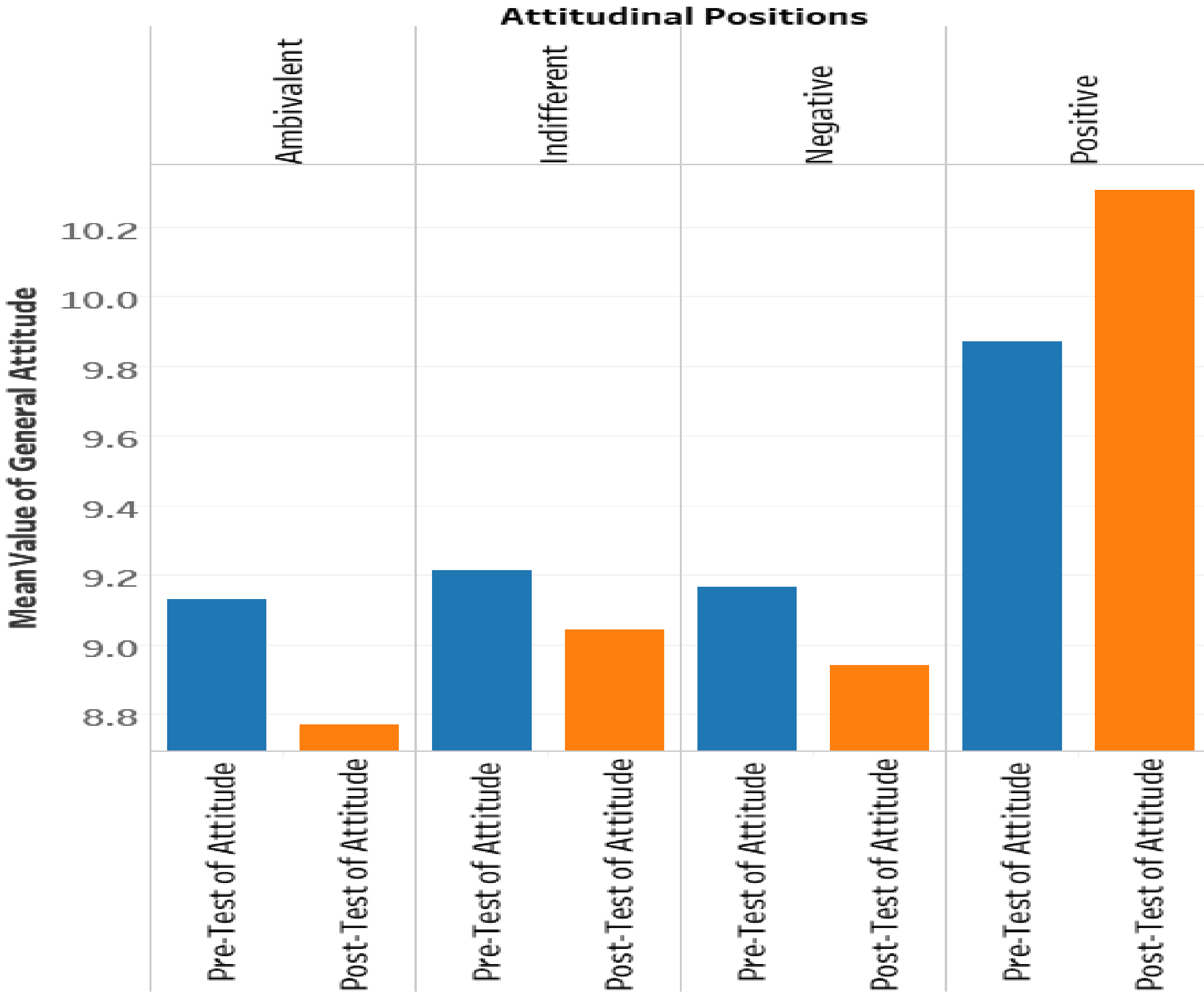
Student knowledge of Graphing-slop Intercept was examined two times before (pre-test) and after (post-test) performing the GSI game. The *t*-test was used to investigate the effect of DGBA (GSI) on students' *knowledge and skill acquisition* (the knowledge of Graphing-slop

Intercept). The results revealed that the post-test mean (*M = 6.214, SD = 1.22*) of the Experimental Group increased significantly compared with the pre-test (*M = 5.53, SD = 0.966*), $t(219) = 7.931$, $p < .001$, indicating that the game of GSI has improved student performance on the Graphing-slop Intercept. To confirm this effect, the Control group has been scrutinized too, and the results showed that the mean difference was not significant for the Control group in the pre and post-test ($t(261) = 2.632$, $p > .09$).

To examine the improvement of participants' general attitudes toward DGBA, the total scores of attitudes towards DGBA in the Experimental group were analyzed before and after using the game of GSI. The results showed that there was a significant difference between the mean of attitude before and after using GSI in the *ambivalent group*, $t(219) = 1.87$, $p < .05$ (Figure 20). This result indicated that the *ambivalent attitude* reduced significantly after using the game of GSI. Also, for the group of *positive attitudes,* the difference between the pre and post-test was significant, $t(219) = -3.53$, $p < .001$. That is, the game of GSI could improve their attitude. However, there were no significant differences in attitude before and after using the game of GSI in *indifferent* and *negative* groups. These results indicated that both *indifferent* and *negative* groups remained stable at the same level of attitudes. (Figure 20).

Figure 20

The General Attitude toward DGBA (GSI) in each Attitudinal Position after and before Using GSI.



Chapter V: Discussion and Implications

The emergence of new digital educational technology (e.g., smart classes or rooms (Sharrab et al., 2023), educational apps (Elsherbiny & Al Maamari, 2021), educational digital games (Ratnasari et al., 2023), and virtual objects (Bogiannidis et al., 2022) is affecting different aspects of education from elementary to higher education. New digital technology has profoundly changed campus structure, curriculum, teaching methods, learning methods, course contents, assessments, academic performance, and other aspects of the educational system. Digital game-based assessment (DGBA) was recently researched among different types of new digital technology.

However, unlike previous studies of DGBA, the present research focused on university students' attitudes toward DGBA, the effects of using digital educational games on attitudes toward such games and educational subject matter (GSI), and the effects of attitude on knowledge and skill acquisition through an experimental treatment. Additionally, instead of using a one - or two - dimensional perspective of attitude (Haddock & Maio, 2008), a multi-dimensional model of attitude (four-way typology model) was used in this study. This model explored four positions (positive, negative, ambivalent, and indifferent attitudes) along with three dimensions of attitude (affective, cognitive, and behavioural). In other words, unlike previous research examining positive or negative perceptions of DGBA, the current research used a tripartite model of attitude components and a four-way typology model. In a three-dimensional conceptual model, the attitude was defined based on the cognitive, emotional, and behavioural aspects of attitude. Also, through a four-way typology model, the attitude scale measured whether a person's attitude is positive, negative, ambivalent, or indifferent. These models helped the researcher to examine three essential research questions: 1) What are students' attitudes toward DGBA in terms of the tripartite - cognitive, affective, and behavioural - system of attitude before and after using a DGBA? 2) What are the students' attitudes toward DGBA in terms of the four-way typology and attitudinal space model? 3) Is

DGBA effective in improving students' knowledge and skill acquisition (Knowledge of Graphing-slop Intercept) and their general attitudes toward DGBA (e.g., GSI)? To answer these questions, a survey method and a pre-and post-test experimental design with two groups of samples were used, and the findings of this research were discussed as follows.

Improved Attitude toward DGBA and Predictors

In the pre-test and before playing GSI, most participants had more or less experience in playing digital games, had less satisfaction with playing digital games, spent from little to somewhat time on educational games, and had very little or little effort to find such educational games (see Table 4). These findings displayed that the students' attitudes were not positive in all components of attitude (affective, cognitive, and behavioural). The possible factors for this result revealed that most students did not have intense experiences using educational games such as GSI or other statistical games. These low experiences and little satisfaction might have caused them to express negative or indifferent attitudes toward using the digital educational game. Besides these results, previous studies revealed that university students had math and statistics anxiety showing negative attitudes toward learning math (Asgari, 2015;-Soleymani & Rekabdar, 2015). Thus, students had not only negative or indifferent attitudes toward digital educational games, and they also had math or statistics anxiety.

However, after playing the digital educational game of GSI, the Experimental group displayed significant changes in their attitudes compared to the Control group. These changes happened in all three attitude aspects (affective, cognitive, and behavioural). Considering the game of GSI as a mathematical and statistical game, this result aligned with the findings of Mavridis et al. (2017), who demonstrated that digital educational games could positively change students' perceptions of mathematics.

Since examining students' experience in using educational digital games showed that their experience was from low to somewhat, it could be suggested that changing their attitude after playing GSI is related to the novelty of such games in their educational settings. Although Iranian youth play different digital games using mobile or tablet, GSI, as an educational digital game, was a new source of learning for them. This result may be different for other cultures, such as Canada, in which using digital games is prevalent. However, this suggestion should be researched in other cultures.

Also, the current results supported DeLegge's and Ziliak's (2021) findings on the effects of digital games on students' math attitudes. In their study, they developed a math course integrated with games as a "Math Games Seminar" at Benedictine University (USA). The course was first run in the fall of 2017 and has been run each semester at the Department of Mathematical & Computational Sciences. The program was popular among undergraduate students since their attitude toward math has changed positively through this course (DeLegge & Ziliak, 2021).

Comparing students' general attitudes toward DGBA before and after using the digital game of GSI revealed that these positive changes were significant. Although the changes were in all components of attitude, the behavioural constituent in the Experimental group had more positive changes than the other aspects. The results indicated that the GSI provided students with a new and practical experience allowing them to learn statistical concepts and formulas quickly through playing a game. One major inquiry in examining students' attitudes toward DGBA was related to the characteristics of DGBA. The current research inquired which aspects or features of DGBA (GSI Game) could bring these changes and to what degree. The regression analysis with the stepwise method was used to answer this question. Of different aspects of DGBA, four characteristics, including game rules, enjoyability, engageability, and understandability (comprehensibility), could predict a 30% variability of attitude toward DGBA.

In other words, these aspects of GSI attracted students' views and changed their attitudes positively. These features of DGBA, along with other aspects such as creating motivation, proper time of the game, and making players relaxed, could predict 24%, 22%, and 13% of cognitive, affective, and behavioural components of attitude toward DGBA, respectively. These features were related to the mechanical, gamification, and content elements of DGBA.

Examining the Four-Way Typology of Attitude Model

Unlike the bipolar perspective of attitude, in which only positive and negative dimensions of attitude were central in previous research, the present study used the four-way typology model of attitude. This model defined attitude orientations in four positions, including positive, negative, indifferent, and ambivalent. The model was tested in this research, and the results revealed that all positions could be differentiated when the general attitude toward DGBA was considered. That is, individuals could be placed in four different positions meaningfully. This model capacity was previously supported (Liu, 2020; Poortinga & Pidgeon, 2006; Reich-Stiebert et al., 2019).

However, when the game of GSI was used, the positions of indifferent and ambivalent attitudes did not separate from each other significantly. In contrast, the positive and negative positions were clearly differentiated from ambivalent and indifferent positions. This problem was reported previously in other studies (Liu, 2020). To easily distinguish these attitudinal positions (indifferent and ambivalent), Liu (2020) used a formula of $\text{Ambivalence} = (P + N)/2 - | P - N|$. However, the present research failed to find evidence to support Liu's formula. There are some possible explanations for this finding. First, the involvement and certainty as two separators cannot effectively distinguish indifferent and ambivalent positions. Second, the capacity of GSI to distinguish these attitudinal positions is possibly low. Finally, the treatment of GSI was not repeated several times, and a one-time treatment might not be enough to differentiate these positions from each other.

Many researchers emphasized distinguishing ambivalent and indifferent attitudes is essential (Lewis, 2017; Liver et al., 2007; Neto et al., 2022). Lewis (2017) argued that differentiating positive and negative attitudes is easy and displays people's direct approach toward or avoidance of an object. Individuals with negative attitudes do not intend to seek advice or get involved in any subjects (business or education). In his view, identifying ambivalent and indifferent attitudes can moderate avoidance and approach behaviours. When people have strong avoidance–approach conflict, they show ambivalence with weak intention and weak motivation to perform something (such as seeking advice or using an object). The weak avoidance–approach conflict creates an indifferent attitude with almost the same results. However, the intention of people with indifferent attitudes to do something would be neither hindered nor facilitated. For people with indifferent attitudes, an object (e.g., using digital educational games, participating in an activity, etc.) does not have any benefit, and they do not even intend to consider the possible benefits of an object.

In contrast, ambivalent people would consider the benefits and may change their view toward an object easier than indifferent people. In line with Lewis' (2017) discussion, the current research revealed that those students with ambivalent attitudes could change their attitude to the positive side after playing the game of GSI. This change is related to the benefits they find in such games. As discussed above, some characteristics of DGBA provided participants with apparent benefits of DGBA, such as reducing stress, understanding the concept of GSI, and engaging them in learning. However, Liver et al. (2007) argued that individuals with ambivalent attitudes spend more time deciding on something since they are in a robust avoidance-approach conflict and have difficulty identifying and separating an object's bad or good aspects. Therefore, making decisions on something became more challenging for them.

The present research results confirm that the affective and cognitive components of attitude in the ambivalent group at the pre-test were higher than the behavioural component (see Figure 18 and Table 11). Considering that the behavioural component is related to people's actions and decisions, this result revealed that participants' actions (such as buying or playing digital educational games) were weak during the pre-test. However, Liver et al. (2007) suggested that to facilitate their decision on using or doing something (such as using digital educational games), the positive aspects of that activity or object should be increased by more practice or providing them with more positive information about the possible benefits of an activity or object. As this research showed, the treatment of GSI digital game could change ambivalent attitudes positively since it feasibly introduces more positive benefits of digital educational games. However, the changes might be more significant if the treatment (such as using the digital game of GSI) were administered several times.

When the results of indifferent and negative attitudes were considered, no significant differences in attitude before and after using the game of GSI in indifferent and negative groups were found. Compared to ambivalent position, indifferent and negative attitudinal positions toward DGBA and its roles in knowledge and skill acquisition remained stable before and after using the game of GSI. In other words, those individuals who were negative or indifferent before using the game of GSI maintained their attitudinal positions even after finishing the treatment.

This finding supported previous research indicating that indifferent and negative people are consistent in their attitudinal positions (Ng et al., 2022; Thornton, 2011). This consistency was remarkable regardless of the object, political decision (Thronton, 2011) or business activity (Lewis, 2017). Unlike the indifferent group, Thronton (2011) found that ambivalent people are in a conflict and tend to seek out information in different ways to facilitate their decision and reduce their ambivalent position.

In line with these studies, the current research found that the ambivalent group was not very stable in their attitudes after the treatment of the digital game since the number of ambivalent attitudes reduced significantly after using the game of GSI. This result is also aligned with the Cognitive Dissonance Theory (Festinger, 1957), in which people with ambivalent attitudes are more likely to change their attitudes when practically facing the advantages of participating in a specific action (Harmon-Jones & Mills, 2019). That is, individuals are ready to change their attitude positively when their behaviours in doing something provide them with more advantages than what they believed before. Using this conceptualization (Cognitive Dissonance Theory), It is reasonable to assume that playing the digital game of GSI can provide students with more opportunities for learning and progress than they previously thought.

GSI and Knowledge and Skill Acquisition

According to the literature review, digital educational games could positively affect different aspects of academic performance, such as increasing deeper learning (Al-Azawei et al., 2019; Arias, 2014; Wang, 2018), improving cognitive skills (Colzato et al., 2010), and engagement in learning assessment (Wang, 2018). To examine whether the game of GSI can have these effects, the knowledge of GSI was used as an index of knowledge and skill acquisition. The results revealed that the treatment of GSI could increase the knowledge and skill acquisition mean for the Experimental group. This aligned with previous research (Al-Azawei et al., 2019; Arias, 2014; Wang, 2018). In detail, the current study demonstrated that the game of GSI could facilitate students' understanding of main regression concepts lines such as Line Slope, Line Intercept, Line Symmetry, and Regression Equation. Also, students could better ratiocinate the relationship between slope and intercept by using the game of GSI. This result aligns with what Chan and Ismail (2014) reported regarding improving students' understanding of statistical concepts after using DGBA.

Validation of Computer Game Attitude Scale (CGAS)

Initially, the CGAS was designed to assess players' attitudes toward computer gaming (Chappell & Taylor, 1997). The scale was developed in 2013 by adding some items to assess two new constructs, including *comfort* (users' confidence in playing computer games) and *liking* (users perceived enjoyment of playing computer games; Liu et al., 2013). With 60 items, the second version of the scale was lengthy and time-consuming. Accordingly, Chang et al. (2014) attempted to reduce the items of CGAS into 17 items to measure three main components, affective, cognitive, and behavioural. The validation of the shortened version by Chang et al. (2014) revealed that the scale has high reliability and validity. (Chang et al., 2014).

CGAS was developed initially in English. To use the scale with Iranian samples, this research translated the scale into the Persian language. After translation and back translation by experts in both English and Iranian language, the data for validation were collected, and Mplus calculated CFA. The validation confirmed that the scale measures three behavioural, cognitive, and affective components of attitude successfully toward digital computer games. The affective component is related to students' liking, comfortableness, interest, and imagination of the game.

The cognitive component refers to easiness, learning, getting skills, and understanding the game. The behavioural component also deals with students' tendency to talk and play computer games.

This result was in line with previous validation done by Liu et al. (2013) and Chang et al. (2014). Moreover, the scale's reliability aligned with what Chen et al. (2027) found. The validation of all items revealed that the items are not sensitive to cultural differences and can be considered as a multi-cultural scale.

Implications and Recommendations

This study raises several potential implications for a) university administrators, educators, and educational policymakers and b) future researchers.

A. Implications for Educational Stakeholders

For Canadian universities to remain competitive and produce or use highly qualified tools for students' deeper learning, it is pivotal that university administrators, educators, and educational policymakers put more effort into understanding the characteristics and functions of new learning and assessment technology. DGBA is one of the various educational tools that have the potential to promote teaching and learning profoundly. However, different aspects of DGBA have not been researched scientifically. The purpose of this study was to shed light on some aspects of DGBA, and the aim was to bridge previous gaps and offer practical implications for educational systems.

1. The current research demonstrated that DGBA could affect knowledge and skill acquisition positively. Therefore, it is recommended that educators consider using an appropriate DGBA for teaching various subjects. For example, the game of GSI can be used to teach the statistical concepts of regression effectively.

2. Traditionally, it is argued that better outcomes could be predicted when an educational subject contains both cognitive and affective materials (Neg, 2022). Cognitive materials are related to pure educational information about a given subject, and affective materials refer to attractive and pleasurable ways of teaching the subject matter (Neg, 2022). Aline with other studies (Barber, 2021), the current research revealed that DGBA has the potential to incorporate different affective (through gamification elements), cognitive (through the content of matter), and behavioural (hands-on aspects of a subject) aspects of an educational subject matter to attract students' attention and engage them in educational activities. Considering individual psychological differences is essential for educational systems. Some may have affectively oriented attitudes, and others might have cognitively oriented attitudes (Neg, 2022). Thus, for those students who pay attention to the attractiveness of a given subject, incorporating the subject with a pleasurable story could be effective in their learning progression. Providing various information could be effective for students who are cognitive-based, and for those who are behavioural, using hands-on methods to teach could be helpful. To identify students' affective, cognitive, and behavioural orientations, it is recommended that educators use attitude scales such as APDG and CGAS.
3. As Barber (2021) argued, incorporating educational subjects with gamification will enhance students' motivation and learning progression. In line with Barber's (2021) findings and theoretical view, this research demonstrated that after using the educational game of GSI, students' learning orientation, motivation, and subject progress changed positively.

4. Although the present research just focused on one subject related to math, the obtained results suggested that digital educational games could be used in the other areas of STEM (science, technology, engineering, and mathematics). In support of previous research (Wang et al., 2022), embedding the contents of STEM in educational games may positively affect students' attitudes and knowledge and skill acquisition (Wang et al., 2022).
5. Current research findings suggest that educators and researchers could use the four-way typology model of attitude to evaluate the success of students' learning programs to differentiate different aspects of attitudes. As previously mentioned, this will allow educators to approach students who have indifferent or ambivalent attitudes differently to help them. Assisting ambivalent and indifferent students in gaining a better understanding of the positive aspects of a program or subject matter can help alleviate conflict situations and increase motivation for success.
6. In the Experimental group, approximately 90% of the samples believed that playing GSI enhanced their understanding of statistical concepts by making it authentic, easy, and enjoyable. Also, this digital game could reduce their stress in learning. It is suggested that universities promote the use of DGBA for teaching and assessment among instructors, given the similarities between GSI and other DGBAs.

B. Implications for Future Researchers

1. The four-way typology model of attitude is a relatively new concept, leaving ample room for future researchers to explore its ability to evaluate attitudes towards various subjects, such as literacy, social science, and other subjects, and compare its advantages and disadvantages with the binary model of attitude.

2. The research examined seven aspects of digital game potential, but other elements could be worth exploring in future studies. It is advisable to investigate and prioritize those aspects.
3. Based on the advantages of distinguishing the four types of attitudes discussed above, it is suggested that future researchers focus on new ways to differentiate indifferent from ambivalent positions of attitude. Current research revealed that Liu's (2020) formula was ineffective in this study. Since there are two types of involvement psychologically (emotional and practical), further research should examine which type of involvement can differentiate the indifferent and ambivalent positions of attitude. This research examined involvement as a behavioural part of the attitude, and examining other types of involvement is suggested.
4. In line with Janakiraman et al.'s (2021) research in which digital game players had higher behavioural intention than the participants who did not play a digital game, the current research revealed that the behavioural component of attitude was more affected by DGBA. However, the sequential relationships between the components of attitude still need to be studied. Thus, it is an opportunity for further research to focus on the possible hierarchical or cyclic relationships among the components of attitude (cognitive, affective, and behavioural) when DGBA is central to the study.
5. This study did not focus on sex differences concerning using DGBA, attitude, and knowledge and skill acquisition because of unbalanced sample sizes. It is advisable to examine sex variations in all aspects and roles of attitude while examining DGBA.
6. While data gathered through survey and experimental methodology are informative, an in-depth perspective on how students perceive the role of DGBA in their learning

processes is needed. Individual interviews or focus groups could be a valuable resource to better understand the challenges facing students and how they perceive DGBA to impact their attitudes, knowledge and skill acquisition.

7. Although administering GSI once improved students' attitudes, knowledge, and skills, a longitudinal study and repeated educational games are recommended.
8. This study validated the CGAS scale with Iranian samples and confirmed all three scale components. This suggests that it could be used for future research on university samples. However, it is important to assess the scale's psychometric properties in different populations through randomized samples before using it for intended purposes.

Limitations

1. It should be noted that the findings of this research may not apply to all students attending universities due to the fact that the participants were not entirely randomly selected. Although statistical indices showed that the samples were not significantly different from the student population at the targeted university, the interpretation of representativeness should be considered cautiously. However, attempts were made to consider the variabilities in the student population, such as age, sex, and discipline.
2. Since part of the data was collected through self-reported questionnaires, the findings should be interpreted cautiously since the researcher could not know if participants responded inaccurately or with biases.
3. Although participants had adequate time to respond, some confounding variables, such as students' tiredness and distractedness, may interfere with the results and reduce the validity of the research.

References

Acock, A. C. (2005). Working with missing values. *Journal of Marriage and Family, 67*(4), 1012-1028. doi: 10.1111/j.1741-3737.2005.00191.x

Adesoji, F. A (2008). Managing students' attitude towards science through problem-solving instructional strategy. *Anthropologist, 10*(1), 21-24, https://doi.org/10.1080/09720073.2008.11891024

Ahmad, M. (2020). Categorizing game design elements into educational game design fundamentals. In Deliyannis, I. *Game Design and Intelligent Interaction.* 10.5772/intechopen.89971. IntechOpen Publisher. https://www.intechopen.com/chapters/70106

Al-Azawei, A., Baiee, W. R., & Mohammed, M. A. (2019). Learners' Experience Towards e-Assessment Tools: A Comparative Study on Virtual Reality and Moodle Quiz. International *Journal of Emerging Technologies in Learning, 14*(5), 34–50. https://doiorg.ezproxy.msvu.ca/10.3991/ijet.v14i05.9998

Aldemir, T., Celik, B., & Kaplan, G. (2018). A qualitative investigation of student perceptions of game elements in a gamified course. *Journal of Computers in Human Behaviour, 78*, 235-254

Alexiou, A., & Schippers, M. C. (2018). Digital game elements, user experience and learning: A conceptual framework. *Education and Information Technologies, 23*:2545–2567 https://doi.org/10.1007/s10639-018-9730-6

An, Y., & Cao, L. (2017). The effects of game design experience on teachers' attitudes and perceptions regarding the use of digital games in the classroom. *TechTrends: Linking Research & Practice to Improve Learning, 61*(2), 162–170. https://doiorg.ezproxy.msvu.ca/10.1007/s11528-016-0122-8

Annaggar, A., & Tiemann, R. (2017). *Video game-based gamification assessment of problem-solving competence in chemistry education*. [Paper presentation]. Proceedings of the European Conference on Games-Based Learning, 939–943. http://search.ebscohost.com.ezproxy.msvu.ca/login.aspx?direct=true&db=ehh&AN=126280836&site=ehost-live&scope=site

Annetta, L., Mangrum, J., Holmes, S., Collazo, K., & Cheng, M. T. (2009). Bridging reality to virtual reality: Investigating gender effect and student engagement on learning through video game play in an elementary school classroom. *International Journal of Science Education, 31*(8), 1091-1113.

Argasinski, J. K., & Węgrzyn, P., (2019). Affective patterns in serious games. *Future Generation Computer Systems, 92*, 526–538.

Arias, M. (2014). Using video games in education. *Journal of Mason Graduate Research. 1*(2), 49–69.

Bachman, L. F. (2004). *Statistical Analyses for Language Assessment*. Cambridge: Cambridge University Press.

Baker, E. L., Chung, G. & Delacruz, G. C., (2008). Design and validation of technology-based performance assessments. In D. Jonassen, M.J. Spector, M. Driscoll, M.D. Merrill, J. van Merrienbo (Eds.), *Handbook of Research on Educational Communications and Technology* (3rd ed., pp. 596-602). New York: Taylor and Francis e-Library.

Barab, S. A., Sadler, T. D., Heiselt, C., Hickey, D., & Zuiker, S. (2007). Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology, 16*(1), 59-82.

Barbaranelli, C., Lee, C. S., Vellone, E., & Riegel, B. (2014). Dimensionality and reliability of the self-care of heart failure index scales: Further evidence from confirmatory factor analysis. *Research in Nursing & Health, 37*(6), 524-537. DOI: 10.1002/nur.21623

Barber, C. S. (2021). When students are players: Toward a theory of student-centric edu-gamification systems. *Journal of Information Systems Education, 32*(1), 51—64.

Beshlideh, K. (2012). *Research Methods and Statistical Analysis of Research Examples Using SPSS and AMOS.* Shahid Chamran University Inc.

Bogiannidis, N., Southcott, J., & Gindidis, M. (2022). An Exploration of the Lived Experiences of a Visual Art Teacher in a Smart Classroom. *Contemporary Educational Technology, 14*(1), 1–15. https://doi-org.ezproxy.msvu.ca/10.30935/cedtech/11366

Bovermann, K., Weidlich, J., & Bastiaens, T. (2018). Online learning readiness and attitudes towards gaming in gamified online learning - a mixed methods case study. *International Journal of Educational Technology in Higher Education, 15*(1), https://doi-org.ezproxy.msvu.ca/10.1186/s41239-018-0107-0

Brockmyer, J. H., Fox, C. M., Curtiss, K. A., McBroom, E., Burkhart, K. M., & Pidruzny, J. N. (2009). The development of the game engagement questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology, 45*, 624–634.

Buhagiar, L.J., & Sammut, G. (2020). Attitude measurement. In G. Ritzer & C. Rojek (Eds.), *The Blackwell Encyclopedia of Sociology.* (pp.1–4). John Wiley & Sons. http://doi.10.1002/9781405165518.wbeos1587

Butt, P. (2016). *Students' perceptions of game-based learning using Codingame.* International Conference on Information Communication Technologies in Education, ICICTE. Proceedings. https://www.researchgate.net/publication/337335060

Cacioppo, J.T., Gardner, W.L., & Berntson, G.G. (1997). Beyond bipolar conceptualizations and measures: The case of attitudes and evaluative space. *Personality and Social Psychology Review: SAGE Journals. 1*(1), 3–25.

Camilleri, M. A., & Camilleri, A. C. (2017). *The students' perceptions of digital game-based learning.* [Paper presentation]. Proceedings of the European Conference on Games Based Learning, 56–62.

Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, and Social Sciences and Humanities Research Council of Canada (2014). *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans*, December 2014. http://www.pre.ethics.gc.ca/pdf/eng/tcps2-2014/TCPS_2_FINAL_Web.pdf

Cankaya, S., & Karamete, A. (2009). The effects of educational computer games on students' attitudes towards mathematics course and educational computer games. *Procedia Social and Behavioural Sciences, 1,* 145–149. http://doi:10.1016/j.sbspro.2009.01.027

Carpenter, R. C., Lundell, V., & Rubin, B. (2008). Serious games in the global affairs classroom: Student impressions of Pax Warrior as an active learning tool. *Journal of Information Technology & Politics, 4*(2), 117-129.

Cetin Dag N, Turkkan E, Kacar A, Dag H. (2021). Children's only profession: Playing with toys. *North Clin Istanb, 8*(4), 414–420.

Chan, S. W. & Ismail, Z. (2014). A technology-based statistical reasoning assessment tool in descriptive statistics for secondary school students. *The Turkish Online Journal of Educational Technology, 13*(1). 29–46.

Chang, M., Kuo, R., & Liu, E. Z. F. (2014, November). Revised computer game attitude scale. In Proceedings of the International Conference on Computers in Education (pp. 598-607). https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=df19499ffd5f15dc74e820a6fbece7cdc91e4893

Chappell, K. K., & Taylor, C. S. (1997). Evidence for the Reliability and Factorial Validity of the Computer Game Attitude Scale. *Journal of Educational Computing Research, 17(*1), 67–77.

Chen, P., Kuo, R., Chang, M., & Heh, J. S. (2017). The effectiveness of using in-game cards as reward. *Research And Practice in Technology Enhanced Learning, 12*(1), 1—23.

Chinomona, R. (2013). Mobile gaming perceived enjoyment and ease of play as predictors of student attitude and mobile gaming continuance intention. *Mediterranean Journal of Social Sciences, 4*(14). http://doi:10.5901/mjss.2013.v4n14p237

Christensen, L. L., Shyyan, V., & Johnstone, C. (2014). Universal design considerations for technology-based, large-scale, next-generation assessments. *Perspectives on Language and Literacy, 40(*1).

Chu, M-W., & Chiang, A. (2018). Raging skies: Development of a digital game-based science assessment using evidence-centred game design. *Alberta Science Education Journal, 45*(2). 36–47.

Cirak, N. S., & Erol, O., (2020). What are the Factors that Affect the Motivation of Digital Gamers? *Participatory Educational Research, 7*(1), 184–200. http://dx.doi.org/10.17275/per.20.11.7.1

Coggle. (2021). Digital Game Platforms. https://coggle.it/diagram/WdtJS2gXiQABNhhS/t/the-different-types-of-gaming-platforms

Colzato, L. S., van Leeuwen, P. J. A., van den Wildenberg, W. P. M., & Hommel, B. (2010). DOOM'd to switch: Superior cognitive flexibility in players of first person shooter games. *Frontiers in Psychology, 1*(8). https://doi.org/10.3389/fpsyg.2010.00008

Copeland, B. J. (2020). The Modern History of Computing. The Stanford Encyclopedia of Philosophy, Edward N. Zalta (ed.), https://plato.stanford.edu/archives/win2020/entries/computing-history/

Corsini, J. R. (2002). *The Dictionary of Psychology*. Brunner-Routledge.

Cui, Y., Chu, M.-W., Chen, F. (2019). Analyzing student process data in game-based assessments with Bayesian knowledge tracing and dynamic Bayesian networks. *Journal of Educational Data Mining, 11*(1)

Cutumisu, M., Blair, K. P., Chin, D. B., & Schwartz, D. L. (2015). Posterlet: A game-based assessment of children's choices to seek feedback and to revise. *Journal of Learning Analytics, 2*(1), 49–71.

Cutumisu, M., Chin, D. B., & Schwartz, D. L. (2019). A digital game-based assessment of middle-school and college students' choices to seek critical feedback and to revise. *British Journal of Educational Technology, 50*(6), 2977–3003. http://doi:10.1111/bjet.12796

Dawson, C. (2002). *Practical Research Methods: A User-Friendly Guide to Mastering Research Techniques and Projects.* How To Books Ltd, 3 Newtec Place. http://www.modares.ac.ir/uploads/Agr.Oth.Lib.21.pdf

de Klerk, S., & Kato, P. M., (2017). The future value of serious games for assessment: Where do we go now? *Journal of Applied Testing Technology, 18*(S1), 32–37.

DeLegge, A., & Ziliak, E. (2021). The Math games seminar: A mathematical learning community. *Journal of Humanistic Mathematics, 11*(2), 148–166.

Demir G. T., & Bozkurt Mutlu, T. (2019). The digital gaming attitude scale (DGAS): Reliability and validity study. *Sportif Bakış: Spor ve Eğitim Bilimleri Dergisi, 6*(1), 1–18. http://doi: 10.33468/sbsebd.79

Demirbilek, M. & Tamer, S. L. (2010). Math teachers' perspectives on using educational computer games in math education. *Procedia Social and Behavioural Sciences, 9*, 709–716. http://doi:10.1016/j.sbspro.2010.12.2

Denham, A. R., (2018). Using a digital game as an advance organizer. *Educational Technology Research and Development, 66*, 1–24. https://doi.org/10.1007/s11423017-9537-y

DeRosier, M. E., & Thomas, J. M. (2018). Establishing the criterion validity of Zoo U's game-based social emotional skills assessment for school-based outcomes. *Journal of Applied Developmental Psychology, 55*, 52–61. http://dx.doi.org/10.1016/j.appdev.2017.03.001

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *Journal of Applied Educational Technology. 4*(1), 21–31.

Dubas, K. M., & Hill, J. (2013). Guidelines for meetings and presentations in second. *Academy of Educational Leadership Journal, 17*(2), 1–12.

E-learning Industry. (2020). 5 Game Elements That Create Effective Learning Games. https://elearningindustry.com/5-game-elements-create-effective-learning-games

Elsherbiny, M. M. K., & H. Al Maamari, R. H. (2021). Game-based learning through mobile phone apps: effectively enhancing learning for social work students. *Social Work Education, 40*(3), 315–332. https://doi-org.ezproxy.library.dal.ca/10.1080/02615479.2020.1737665

Entertainment Software Association. (2019). Essential facts about the computer and video game industry. https://www.theesa.com/wp-content/uploads/2019/05/2019-Essential-Facts-About-the-Computer-and-Video-Game-Industry.pdf

Entertainment Software Association of Canada, (2019). The Canadian video game industry. https://theesa.ca/wpcontent/uploads/2019/11/CanadianVideoGameSector2019_EN.pdf

Faustino, B. (2022). Maladaptive and Adaptive Cognitions About the Self and Others: Confirmatory Factor Analysis of the Brief Core Schemas Scales. Psychological Reports, 0(0), 1—15. DOI: 10.1177/00332941211063602. https://journals.sagepub.com/doi/10.1177/00332941211063602

Ferchaud, A., Seibert, J., Sellers, N., & Escobar Salazar, N. (2020) reducing mental health stigma through identification with video game avatars with mental illness. *Frontiers Psychology 11*:2240. http://doi: 10.3389/fpsyg.2020.02240

Festinger, L. (1957). *A Theory of Cognitive Dissonance.* Stanford, CA: Stanford University Press.

Firoozabadi, M., Tabesh, H., Hashemi, M. & Saki, A. (2015). Study of Students' Attitudes Toward Biostatistics and Using Technology in Bushehr University of Medical Sciences. *Educational Development of Jundishapur, 6*(4), 347–355.

Garcia-Santillan, A., Moreno-Garcia, E., Carlos-Castro, J., Zamudio-Abdala, J. H. & Garduno-Trejo, J. (2012). Cognitive, affective and behavioural components that explain attitude toward statistics. *Journal of Mathematics Research, 4*(5), 8–16.

Garson, G. D. (2012). *Testing Statistical Assumptions*. Asheboro, NC: Statistical Associates Publishing.

Ghaicha, A. (2016). Theoretical framework for educational assessment: A synoptic review. *Journal of Education and Practice, 7*(24). 212–231.

Giannakas, F., Kambourakis, G., Papasalouros, A., & Gritzalis, S. (2018). A critical review of 13 years of mobile game-based learning. *Educational Technology Research & Development, 66*(2), 341–384. https://doi-org.ezproxy.msvu.ca/10.1007/s11423-017-9552-z

Global Digital Games Market. (2020). Global Digital Games Market 2022 | Global Industry Demand Status with Recent Trends, Size and Share Analysis. https://www.marketwatch.com/press-release/global-digital-games-market- 2022-global-industry-demand-status-with-recent-trends-size-and-share-analysis-2020-03-25

Grady, S. E., Vest, K. M., & Todd, T. J. (2013). Student attitudes toward the use of games to promote learning in the large classroom setting. *Currents in Pharmacy Teaching and Learning, 5,* 263–268. http://dx.doi.org/10.1016/j.cptl.2013.01.008

Gravetter, F. J., & Wallnau, L. B. (2009). *Statistics for the Behavioral Sciences*. Belmont, CA: Thomson/Wadsworth.

Griffin, P. & Care, E., (2015). *Assessment and Teaching of 21st Century Skills Methods and Approach.* Springer. https://link.springer.com/book/10.1007%2F978-94-017-9395-7

GSI. (2021). Graphing Slope-Intercept. University of Colorado Boulder. https://phet.colorado.edu/sims/html/graphing-slope-intercept/latest/graphing-slope-intercepten.html

Haddock G, & Maio G.R. (2008). Attitudes: Content, structure and functions. In: Hewstone M, Stroebe W, Jonas K (eds) *Introduction to Social Psychology,* (4th ed.). Blackwell. 112–133.

Han, S. (2017). Korean students' attitudes toward STEM project-based learning and major selection. *Educational Sciences: Theory & Practice, 17*, 529–548. https://doi.org/10.12738/estp.2017.2.0264

Han, S., & Carpenter, D. (2014). Construct validation of student attitude toward science, technology, engineering, and mathematics project-based learning: The case of Korean middle-grade students. *Middle Grades Research Journal, 9*, 27–41.

Harmon-Jones, E., & Mills, J. (2019). An introduction to cognitive dissonance theory and an overview of current perspectives on the theory. In E. Harmon-Jones (Ed.), *Cognitive Dissonance: Reexamining a Pivotal Theory in Psychology* (pp. 3–24). American Psychological Association. https://doi.org/10.1037/0000135-001

Hazar, Z., & Demir, G. T. (2018), Sınıf Öğretmeni Adaylarının Oyun ve Fiziksel Etkinlikler Dersine Yönelik Tutum Ölçeği: Geçerlik Ve Güvenirlik Çalışması. *Journal of Human Sciences, 15*(2), 1206–1215. http://doi:10.14687/jhs.v15i2.5284

Hebert, C., & Jenson, J. (2018). *Beyond built-in assessment systems: Evaluating digital game-based learning in complex learning environments* [Paper presentation]. Proceedings of the European Conference on Games Based Learning, 221–231. http://search.ebscohost.com.ezproxy.msvu.ca/login.aspx?direct=true&db=ehh&AN=132746054&site=ehost-live&scope=site

Heinzen, T., (2014). *Game-based assessment: Two practical justifications* [Paper presentation]. KDD Annual Computer Science Conference. NY. New York. https://www.researchgate.net/profile/Thomas-Heinzen-2/publication/271515597_Game-Based_Assessment_Two_Practical_Justifications/links/54ca63ad0cf2517b755e0620/Game-Based-Assessment-Two-Practical-Justifications.pdf

Hellerstedt, A. & Mozelius, P. (2019). Game-based learning - a long history [Paper presentation]. Irish Conference on Game-based Learning, Cork, Ireland https://www.researchgate.net/publication/336460471

Helm, P. J., Rothschild, L. G., Greenberg, J., & Croft, A. (2018). Explaining sex differences in existential isolation research. *Personality and Individual Differences, 134*, 283–288.

Högberg, J., Hamari, J., & Wästlund, E. (2019). Gameful experience questionnaire (GAMEFULQUEST): an instrument for measuring the perceived gamefulness of system use. *User Modeling and User-Adapted Interaction, 29*, 619–660. https://doi.org/10.1007/s11257-019-09223-w

Holmgren, H., & Ståhl, F. (2016). Animated vs. Static graphics in a video game. How does animated and static graphics affect the user experience in a game?. Linköping University Electronic Press. https://www.divaportal.org/smash/get/diva2:1040895/FULLTEXT01.pdf

Hooman, H. A. (2013). Statistical Inference in Behavioural Research. Samt Publication, Tehran, Iran.

Hooman, H. A. (2010). *Research Methodology in Behavioral Sciences*. Samt Publication, Tehran, Iran. http://samt.ac.ir

Hu, L. t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: *A Multi-disciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hung, C-M., Huang, I., & Hwang, G-J. (2014). Effects of digital game-based learning on students' self- efficacy, motivation, anxiety, and achievements in learning Mathematics. *Journal of Computer Education, 1*(2–3). 151–166. doi 10.1007/s40692-014-0008-8

Hussain, Z., Griffiths. M. D., (2009). The attitudes, feelings, and experiences of online gamers: A qualitative analysis the attitudes, feelings, and experiences of online gamers: A qualitative analysis. *CyberPsychology & Behaviour 12*(6), 747–753. https://doi.org/10.1089/cpb.2009.0059

Ibuot, U. P., (2020). Attitude components and their influence on communication. *African Journal for the Psychological Study of Social Issues, 23*(2), 154–164.

Janakiraman, S., Watson, S. L., & Watson, W. R. (2021). Exploring the Effectiveness of Digital Games in Producing pro-Environmental Behaviors when Played Collaboratively and Individually: A Mixed Methods Study in India. *TechTrends, 65*, 331–347. https://doi.org/10.1007/s11528-020-00571-8

Jöreskog, K. G., & Sörbom, D. (1982). Recent Developments in Structural Equation Modeling. *Journal of Marketing Research, 19*(4), 404–416. https://doi.org/10.1177/002224378201900402

Kazemi, F. & Fatemi, A. (2010). The relationship between students' attitudes toward statistics and probability and their academic achievement. [Paper presentation]. Iran Statistics, 383–391.

Kerlinger, F. N., & Lee, H. B. (1999). Foundations of behavioural research: Quantitative methods in Psychology. *Behaviour Therapy,* 80090-6.

Kickmeier-Rust, M. (2018). *Combinatorial and Psychometric Methods for Game-Based Assessment* [Paper presentation]. Proceedings of the European Conference on Games Based Learning, 299–306.

http://search.ebscohost.com.ezproxy.msvu.ca/login.aspx?direct=true&db=ehh&AN=132746063&site=ehost-live&scope=site

Kim, D.I., & Young-An Ra, Y. (2015). What Impacts Success in College? Findings from the perceptions of Korean students. *College Student Journal, 49*(1), 161–168. https://eric.ed.gov/?id=EJ1095550

Kline, R. B. (2011). *Principles and Practice of Structural Equation Modeling* (3rd ed.). The Guilford Press. https://eds-a-ebscohost-com.login.ezproxy.library.ualberta.ca/eds/ebookviewer/ebook/bmxlYmtfXzEwNzg5MTdfX0FO0?sid=af2321f2-c5eb-4f7f-a6af-a94a4430cf49@sdc-v-sessmgr03&vid=2&format=EB&rid=3

Kolek, L., & Sisler, V. (2017). Representation of history in computer games and attitude change: empirical study design [Paper presentation]. European Conference on Games Based Learning, 829–834. http://search.ebscohost.com.ezproxy.msvu.ca/login.aspx?direct=true&db=ehh&AN=126280822&site=ehost-live&scope=site

Kordaki, M. & Gousiou, A. (2017). Digital card games in education: A ten-year systematic review. *Computers & Education 109*, 122–161. http://dx.doi.org/10.1016/j.compedu.2017.02.011

Krejcie, R.V., & Morgan, D.W. (1970). Determining Sample Size for Research Activities. *Educational and Psychological Measurement, 30*, 607-610. https://doi.org/10.1177/001316447003000308

Kreutzer, C. P., & Bowers, C. A. (2015). Attitudes toward a game-based approach to mental health. *CyberPsychology, Behaviour & Social Networking, 18*(1), 20–24. https://doi.org/10.1089/cyber.2014.0382

Kruglanski, A. W., Baldner, C., Chernikova, M., Lo Destro, C., & Pierro, A. (2018). A new perspective on the attitude-behaviour relation: The essential function of goals. *Polish Psychological Bulletin, 49*(1). http://doi.org/10.1515/ppb-2018-00xx

Kruglanski, A. W., Jasko, K., Chernikova, M., Milyavsky, M., Babush, M., Baldner, C., & Pierro, A. (2015). The rocky road from attitudes to behaviours: Charting the goal systemic course of actions. *Psychological Review, 122*(4), 598–620. https://doi.org/10.1037/a0039541

Kuo, C.-Y. & Wu, H.-K. (2013). Toward an integrated model for designing assessment systems: An analysis of the current status of computer-based assessments in science. *Computers & Education, 68*, 388–403. https://doi.org/10.1016/j.compedu.2013.06.002

Kurniawan, D., & Wahyuningsih, T. (2018). Analysis of Student Difficulties in Statistics Courses. *International Journal of Trends in Mathematics Education Research, 1*(2), 53–55. doi:10.33122/ijtmer.v1i2.39

Lee, H.-M., Song, H.-J., Lee, C.-K., & Reisinger, Y. (2019). Formation of festival visitors' environmentally friendly attitudes: cognitive, affective, and conative components. *Current Issues in Tourism, 22*(2), 142–146. https://doi.org/10.1080/13683500.2017.1381668

Lenhart, A., Jones, S., & Macgill, A. (2008). *Teens, video games and civics.* Pew Research Center. https://eric.ed.gov/?id=ED525058

Leon-Mantero, C., Casas-Rosal, J. C., Maz-Machado, A., & Rico, M. E. V. (2020). Analysis of attitudinal components towards statistics among students from different academic degrees. *PLoS ONE, 15*(1), 1–13. https://doi.org/10.1371/journal.pone.0227213

Lepper, M. R., & Greene, D. (1975). Turning play into work: Effects of adult surveillance and extrinsic rewards on children's intrinsic motivation, *Journal of Personality and Social Psychology, 31*(3), 479. https://doi.org/10.1037/h0076484

Lewis, D. (2017). Ambivalent *but not indifferent: consumer motivations to seek versus avoid professional advice*. [Doctoral dissertation, Wilfrid Laurier University]

Liao, H. A., Ferdenzi, A. C., & Edlin, M. (2012). Motivation, self-regulated learning efficacy, and academic achievement among international and domestic students at an urban community college: A comparison. *Community College Enterprise.* 9–38. https://search.proquest.com/openview/445180ecdb608fc4f6204cb243fb2d8f/1?pq-origsite=gscholar&cbl=26254

Lichtenstein, S. & Slovic, P. (2006). *The construction of preference.* New York: Cambridge University Press.

Lindqvist, A., Gustafsson Sendénb, M., & Renströmc, E. A. (2020). What is gender, anyway: a review of the options for operationalising gender. *Psychology & Sexuality,* https://doi.org/10.1080/19419899.2020.1729844

Liver, Y., van der Pligt, J., & Wigboldus, D. (2007). Positive and negative associations underlying ambivalent attitudes. *Journal of Experimental Social Psychology 43*. 319–326. doi:10.1016/j.jesp.2006.02.012

Liu, P. (2020). Positive, negative, ambivalent, or indifferent? Exploring the structure of public attitudes toward self-driving vehicles on public roads. *Transportation Research Part A, 142*, 27–38. https://doi.org/10.1016/j.tra.2020.10.008

Liu, E. Z.-F., Lee, C.-Y., & Chen, J.-H. (2013). Developing a new computer game attitude scale for Taiwanese early adolescents. *Educational Technology & Society, 16* (1), 183–193. https://www.jstor.org/stable/jeductechsoci.16.1.183

Maganty, N., Ilyas, M., Zhangb, N., & Sharma, A. (2018). Online, game-based education for melanoma recognition: A pilot study. *Patient Education and Counseling, 101*; 738–742. https://doi.org/10.1016/j.pec.2017.11.003

Mahmoudi, H., Koushafar, M., Amani Saribagloo, J., & Pashavi, G. (2015). The effect of computer games on speed, attention, and consistency of learning mathematics among students. *Procedia - Social and Behavioural Sciences, 176*, 419–424. https://doi.org/10.1016/j.sbspro.2015.01.491

Margolis, E., & Laurence, S. (2011). Learning matters: The role of learning in concept acquisition. *Mind & Language, 26*(5), 507-539. https://doi.org/10.1111/j.1468-0017.2011.01429.x

Marti-Parreno, J., Galbis-Cordova, A., & Miquel-Romero, M. J. (2018). Students' attitude towards the use of educational video games to develop competencies. Computers in Human Behaviour, 81, 366–377. https://doi.org/10.1016/j.chb.2017.12.017

Martin, R. (2008). New possibilities and challenges for assessment through the use of technology. In F. Scheuermann & A. G. Pereira (Eds.), *Towards a Research Agenda on Computer-Based Assessment.* Luxembourg: Office for Official Publications of the European Communities.

Martinez-Martinez, C., Richart-Martínez, M., & Ramos-Pichardo, J. D. (2020). Operational definition of serious mental illness: heterogeneity in a review of the research on quality-of-life interventions. *Journal of the American Psychiatric Nurses Association, 26*(3), 229-244. https://doi.org/10.1177/1078390320902823

Mathe, M., Verhagen, H., & Wiklund, M. (2019). Digital games-based teaching in Swedish compulsory and upper secondary schools [Paper presentation]. European Conference on Games Based Learning, 503–511. http://doi-org/10.34190/GBL.19.079

Mavridis, A., Katmada, A., & Tsiatsos, T. (2017). Impact of online flexible games on students' attitude towards mathematics. *Educational Technology Research & Development, 65*(6), 1451–1470. https://doi.org/10.1007/s11423-017-9522-5

McCord, J.-L., Harman, J.-L., & Purl, J. (2019). Game-like personality testing: An emerging mode of personality assessment. *Personality and Individual Differences 143*, 95–102. https://doi.org/10.1016/j.paid.2019.02.017

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-kennicutt, W., & Davis, J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education, 70,* 29–40. http://doi.org/10.1016/j.compedu.2013.07.033

Meyers, G. L., Gamst, G. & Guarino. A. J. (2006). *Applied Multivariate Research: Design and Interpretation.* SAGE Publications.

Mircioiu, C., and Atkinson, J. (2017). A comparison of parametric and non-parametric methods applied to a likert scale. *Pharmacy 5*(2), 26. https://doi.org/10.3390/pharmacy5020026

Mordor Intelligence (2020). *Serious games market - growth, trends, covid-19 impact, and forecasts (2021 - 2026).* https://www.mordorintelligence.com/industry-reports/serious-games-market

Mousa, M. (2017). Technology-based assessment and enhancement of thinking skills: A case study of the educational system development in Palestine. *International Humanities Studies, 4*(2), 22–33. ISSN 2311-7796 Online.

Najdi, S. & El Sheikh, R. (2012). Educational games: do they make a difference? *Procedia Social and Behavioural Sciences, 47,* 48–51. https://doi.org/10.1016/j.sbspro.2012.06.612

Namli, S., & Demir, G. T., (2020). The relationship between attitudes towards digital gaming and sports. *TOJET: The Turkish Online Journal of Educational Technology, 19*(1), 40-52. https://eric.ed.gov/?id=EJ1239946

Neto, D. H., Carvalho, S. D., Ribeiro, P. A., Lavoie, K. L., Bacon, S. L., & Cornélio, M. E. (2022). Methods to assess ambivalence toward food and diet: A scoping review protocol. *JBI Evidence Synthesis, 20*(4), 1142-1149.

Ng, W. J. R., See, Y. H. M., & Wallace, L. E. (2022). When Objective Ambivalence Predicts Subjective Ambivalence: An Affect–Cognition Matching Perspective. *Personality and Social Psychology Bulletin,* 1—16. Doi:01461672221102015

Oblinger, D. (2004). The next generation of educational engagement. *Journal of Interactive Media in Education,* (8), 1–18.

Office of Privacy Commissioner of Canada (2019). Gaming and personal information: Playing with privacy. https://www.priv.gc.ca/en/privacytopics/technology/mobile-and-digital-devices/digital-devices/gd_gc_201905/

Okanlawon, A.E., Fakokunde, J.B., Yusuf, F.A., Abanikannda, M.O., & Oyelade, A.A. (2017). Attitudes towards instructional games on Peace Education among second year students in junior secondary schools in South-west Nigeria. *International Journal of Education & Development Using Information & Communication Technology, 13*(3), 98–108. http://search.ebscohost.com.ezproxy.msvu.ca/login.aspx?direct=true&db=ehh&AN=127440354&site=ehost-live&scope=site

Olfos, R., & Zulantay, H. (2007). Reliability and validity of authentic assessment in a web-based course. *Educational Technology & Society, 10*(4), 156–173.

Organization for Economic Co-operation and Development (2018). The future of education and skills Education 2030: The future we want. *Organization for Economic Co-operation and Development, OECD Publishing*. https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf

Pasztor, A., Molnar, G., Csapo, B. (2015). Technology-based assessment of creativity in educational context: the case of divergent thinking and its relation to mathematical achievement. *Thinking Skills and Creativity,* 1–11. http://dx.doi.org/10.1016/j.tsc.2015.05.004.

Pellegrino, J. W & Quellmalz, E. S. (2010). Perspectives on the integration of technology and assessment. *Journal of Research Technology and Engineering, JRTE. 43*(2), 119–134. www.iste.org

Piaget, J. (1973). *To Understand Is to Invent.* New York: Grossman.

Pigott, T. D. (2001). A review of methods for missing data. *Educational Research and Evaluation, 7*(4), 353-383. doi: 10.1076/edre.7.4.353.8937

Pittman, L. D., & Richmond, A. (2007). Academic and psychological functioning in late adolescence: The importance of school belonging. *Journal of Experimental Education, 75(*4), 270–290. https://doi-org.ezproxy.msvu.ca/10.3200/JEXE.75.4.270-292

Plass, J. L., Homer, B. C., & Kinzer, C. K., (2015). Foundations of Game-Based Learning. *Educational Psychology, 50*(4), 258–283. https://www.tandfonline.com/doi/abs/10.1080/00461520.2015.1122533

Pohl, M., Rester, M., & Judmaier, P. (2009, July). *Interactive game-based learning: Advantages and disadvantages* [Paper presentation]. International Conference on Universal Access in Human-Computer Interaction, 92–101. Springer, Berlin, Heidelberg.

Polyak, S. T., von Davier, A. A., & Peterschmidt, K. (2017). Computational psychometrics for the measurement of collaborative problem-solving skills. *Frontiers in Psychology, 8:*2029. doi: 10.3389/fpsyg.2017.02029

Poortinga, W., & Pidgeon, N. F. (2006). Exploring the Structure of Attitudes Toward Genetically Modified Food. *Risk Analysis, 26*(6), doi: 10.1111/j.1539-6924.2006.00828.x

Price, P. C., Jhangiani, R. S., Chiang, I. A., Leighton, D. C., & Cuttler, C. (2017). *Research Methods in Psychology* (3rd American Edition). PressBooksPublications.

Quellmalz, E. S., Davenport, J. L., Timms, M. J., DeBoer, G. E., Jordan, K. A., Huang, C., & Buckley, B. C. (2013). Next-generation environments for assessing and promoting complex science learning. *Journal of Educational Psychology, 105*(4), 1100–1114. doi:10.1037/a0032220.

Ranalli, J. (2008). Learning English with The Sims: exploiting authentic computer simulation games for L2 learning. *Computer Assisted Language Learning, 2*1(5), 441-455.

Ratnasari, W., Tzu-Chuan Chou, & Chen-Hao Huang. (2023). Exploring the Research Trajectory of Digital Game-based Learning: A Citation Network Analysis. *Journal of Educational Technology & Society, 26*(1), 45–61. https://doi-org.ezproxy.library.dal.ca/10.30191/ETS.202301_26(1).0004

Redecker, C., (2013). *The Use of ICT for the Assessment of Key Competences.* Publications Office of the European Union.

Reich-Stiebert, N., Eyssela, F., & Hohnemannb, C., (2019). Involve the user! Changing attitudes toward robots by user participation in a robot prototyping process. *Computers in Human Behaviour, 91*, 290–296.

Rekabdar, Gh., & Soleymani, B. (2008). Attitude toward Statistic based on the computer technology after university Statistic course. *Curriculum Planning Knowledge & Research in Educational Sciences, 19*(3), 117–132.

Saadat, M., Ghasemzadeh, A., & Soleimani, M. (2012). Self-esteem in Iranian university students and its relationship with academic achievement. *Procedia - Social and Behavioural Sciences, 31,* 10–14. doi:10.1016/j.sbspro.2011.12.007

Saffari, R. (2016a). Examining the role of the game in teaching of Mathematics. [Paper presentation]. The First National Conference of Statistic and Mathematics. 3966–3971.

Saffari, R. (2016b). Examining the role of the Origami game in teaching of basic Geometry. [Paper presentation]. The First National Conference of Statistic and Mathematics. 265–273.

Salend, S. J. (2009). Technology-Based classroom assessments alternatives to testing. *Teaching Exceptional Children, 41*(6), 48–58.

Sanchez-Mena, A., Martí-Parreño, J., & Aldás-Manzano, J. (2019). Teachers' intention to use educational video games: The moderating role of gender and age. *Innovations in Education and Teaching International, 56*(3), 318–329. https://doi-org.ezproxy.msvu.ca/10.1080/14703297.2018.1433547

Schauer, J. M., & Hedges, L. V. (2021). Reconsidering statistical methods for assessing replication. *Psychological Methods, 26*(1), 127–139. https://doi-org.ezproxy.msvu.ca/10.1037/met0000302

Schwarz, N. & Bohner, G. (2001). The Construction of Attitudes. In A. Tesser & N. Schwarz (Eds.), *Intrapersonal Processes (Blackwell Handbook of Social Psychology),* (436–457). Blackwell,

Scottish Government. (2016). *Enhancing Learning and Teaching Through the Use of Digital Technology: A Digital Learning and Teaching Strategy for Scotland*. Published by The Scottish Government, Edinburgh, retrieved from https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2016/09/enhancing-learning-teaching-through-use-digital-technology/documents/00505855-pdf/00505855-pdf/govscot%3Adocument/00505855.pdf

Seidl, R., Moser, C., Stauffacher, M., & Pius Krutli, P. (2013). Perceived Risk and Benefit of Nuclear Waste Repositories: Four Opinion Clusters. *Risk Analysis, 33*(6), doi:10.1111/j.1539-6924.2012.01897.x

Shahidi, M. (2020). *The interrelationship amongst depression, loneliness, self-regulation, and academic achievement in Canadian and international students.* [Doctoral dissertation, Canada, Nova Scotia Inter-University Doctoral Program, Mount Saint Vincent University]. http://ec.msvu.ca/xmlui/handle/10587/2161

Shojaee, M., Cui, Y., Shahidi, M., & Zhang, X. (2019). Validation of the questionnaire of students' attitudes toward STEM-PBL: Can students' attitude toward STEM-PBL predict their academic achievement? *Psychology, 10*, 213–234. https://doi.org/10.4236/psych.2019.102017.

Shute, V. J., & Rahimi, S. (2016). Review of computer-based assessment for learning in elementary and secondary education. *Journal of Computer Assisted Learning, 33*(1), 1–42.

Shute, V. J., and Emihovich, B. (2018). Assessing problem-solving skills in game-based immersive environments. In J. Voogt et al. (Eds.), *Second Handbook of Information Technology in Primary and Secondary Education*, (635–648). Springer International Handbooks of Education. https://doi.org/10.1007/978-3-319-71054-9_40

Shute, V. J., Ke, K., & Wang, L. (2016). Assessment and Adaptation in Games. In P. Wouters, & H. van Oostendorp (Eds.), *Techniques to Improve the Effectiveness of Serious Games, Advances in Game-Based Learning* (chapter 4). http://myweb.fsu.edu/vshute/pdf/assess_adapt.pdf. DOI 10.1007/978-3-319-39298-1_4

Snyder, A. I., & Tormala, Z. L. (2017). Valence asymmetries in attitude ambivalence. *Journal of Personality and Social Psychology, 112*(4), 555–576. https://doi-org.ezproxy.msvu.ca/10.1037/pspa0000075.supp (Supplemental)

Soleymani, B. & Rekabdar, G. (2015). Investigating the relationship between reading styles and the academic performance of mathematics with the mediating role of math anxiety. *Education and Evaluation Quarterly, 6*(21). 63-77.

Stanescu, D., Tosca, A., & Ionita, C. G., (2018). Game-based assessment – the new revolution of candidates' assessment. In Constantin C. Bratianu, A. Zbuchea, & A., Vițelar, (Eds.) *Strategica: Challenging the status quo in management and economics.* (480–490). Tritonic Publishing House. Bucharest, Romania.

Steinkuehler, C., & Duncan, S. (2008). Scientific habits of mind in virtual worlds. *Journal of Science Education and Technology, 17*(6), 530–543.

Stoeffler, K., Rosen, Y., Bolsinova, M., & von Davier, A.A. (2019). Gamified performance assessment of collaborative problem-solving skills. *Computers in Human Behaviour*, *104,* 106036. https://doi.org/10.1016/j.chb.2019.05.033

Steinmayr, R., Meißner, A., Weidinger, A. F., & Wirthwein, L. (2015). Academic achievement. Oxford Bibliographies. https://dx.doi.org/10.1093/obo/9780199756810-0108

Suhr, D. (2008). *Step your way through path analysis* [Paper presentation]. 16th Annual Western Users of SAS ® Software Regional Conference, Universal City, California. https://pdfs.semanticscholar.org/aeb5/4396b979b6351cc09a4d0a9109a882de6e67.pdf?_ga=2.172982241.313654120.1559228247-1050185995.1558790786

Sullivan, G. M., & Artino, A. R. (2013). Analyzing and interpreting data from Likert-Type Scales. Journal of Graduate Medical Education. 541-2. DOI: http://dx.doi.org/10.4300/JGME-5-4-18

Tatli, Z. (2018). Traditional and digital game preferences of children: A CHAID analysis on middle school students. *Contemporary Educational Technology, 9*(1), 90–110.

Thornton, J. R. (2011). Ambivalent or Indifferent? Examining the validity of an objective measure of partisan ambivalence. *Political Psychology, 32*(5), 863–884. https://doi-org.ezproxy.msvu.ca/10.1111/j.1467-9221.2011.00841.x

Turan, Z., & Meral, E. (2018). Game-based versus to non-game-based: The impact of student response systems on students' achievements, engagements and test anxieties. *Informatics in Education,* 17(1), 105–116. https://doi-org.ezproxy.msvu.ca/10.15388/infedu.2018.07

Van Eck, R. (2006). The effect of contextual pedagogical advisement and competition on middle-school students' attitude toward mathematics using a computer-based simulation game. *Journal of Computers in Mathematics and Science Teaching, 25*(2), 165–195.

Vankus, P. (2021). Influence of game-based learning in mathematics education on students' affective domain: A systematic review. *Mathematics, 9* (986). https://doi.org/10.3390/math9090986

Vernadakis, N., Gioftsidou, A., Antoniou, P., Ioannidis, D., & Giannousi, M. (2012). The impact of Nintendo Wii to physical education studentsâ balance compared to the traditional approaches. *Computers & Education, 59*(2), 196--205. doi:10.1016/j.compedu.2012.01.003

Voulgari, I., & Lavidas, K. (2020). *Student teachers' game preferences, game habits, and attitudes towards games as learning tools* [Paper presentation]. European Conference on Games Based Learning, 646–654. https://doi-org.ezproxy.msvu.ca/10.34190/GBL.20.175

Wang, D. (2018). Gamified learning through unity 3D in visualizing environments. *Neural Computing & Applications, 29*(5), 1399–1404. https://doi.org/10.1007/s00521-017-2928-5

Wang, L. H., Chen, B., Hwang, G. J., Guan, J. Q., & Wang, Y. Q. (2022). Effects of digital game-based STEM education on students' learning achievement: a meta-analysis. *International Journal of STEM Education, 9*(1), 1-13.

Wang, T., Strobl, C., Zeileis, A., & Merkle, E. C. (2018). Score-based tests of differential item functioning via pairwise maximum likelihood estimation. *Psychometrika, 83(*1), 132–155.

Watson, W. R., Mong, C. J., & Harris, C. A. (2011). A case study of the in-class use of a video game for teaching high school history. *Computers & Education, 56*(2), 466-474.

Weisberg, S. (2005). *Applied Linear Regression* (Vol. 528). John Wiley & Sons.

Wiersma, W., & Jurs, S. G. (2009). *Research Methods in Education: An Introduction*. Pearson Education Inc.

Yambi, T. A. C. (2018). Assessment and evaluation in education. https://www.researchgate.net/publication/342918149_assessment_and_evaluation_in_education.

Yildirim, I. (2017). The effects of gamification-based teaching practices on student achievement and students' attitudes toward lessons. *Internet and Higher Education 33*, 86–92. http://dx.doi.org/10.1016/j.iheduc.2017.02.002

Zheng, D., Young, M. F., Wagner, M. M., & Brewer, R. A. (2009). Negotiation for action: English language learning in game-based virtual worlds. *The Modern Language Journal, 93*(4), 489–511. doi:10.1111/j.1540-4781.2009.00927.x

Zhong, Q. (2019). Design of game-based collaborative learning model. *Open Journal of Social Sciences, 7*, 488-496. https://doi.org/10.4236/jss.2019.77039

Zimmermann, K. A. (2017). History of Computers: A Brief Timeline. *Live Science.* https://www.livescience.com/20718-computer-history.html

Appendixes

Appendix 1

Research Questionnaire

Please answer as many of the questions as possible. You do not have to answer any question that causes you discomfort.

1) **Age:** ☐19 – 23 ☐ 24-30 ☐ 31-36 ☐ > 36

2) **Gender:** ☐ Female ☐ Male ☐ Prefer not to say

   Prefer to Self-describe as ________________

3) **Are you:** ☐ Single ☐ Married ☐ Divorced ☐ Separated ☐ Common Law

   ☐ Other

4) **My current GPA is------------------**

   If you do not remember your GPA, please select one of the following options that best represents your current GPA:

   ☐ **3.7 – 4.3 (A range)** ☐ **2.7 – 3.3 (B range)** ☐ **1.7 – 2.3 (C range)**

   ☐ **1.0 -1.3 (D range)** ☐ **< 1.0**

5) **In what type of environment have you grown?**

   Urban ☐ **Rural** ☐ **Countryside** ☐ **Semiurban** ☐

6) **How much have you played educational digital games before?**

   Very Little ☐ **Little** ☐ **Some** ☐ **Quite a bit** ☐ **A lot** ☐

7) **How much do you engage yourself with the play while playing educational digital games?**

Very Little ☐ Little ☐ Some ☐ Quite a bit☐ A lot ☐

8) **In general, how much do you entertain yourself with educational digital games?**

Very Little ☐ Little ☐ Some ☐ Quite a bit☐ A lot ☐

9) **How satisfied would you be playing educational digital games with your friends?**

Very Little ☐ Little ☐ Some ☐ Quite a bit☐ A lot ☐

10) **How much time do you spend finding educational digital games?**

Very Little ☐ Little ☐ Some ☐ Quite a bit☐ A lot ☐

Appendix 2

The Scale of Prior-Statistical Knowledge

Below are some questions about your Graphing Slope Intercept and Line Equations knowledge. There is just one correct answer for each question, and please choose the correct answer by putting (**X**) in the box.

1- How does "*m*" in the equation $y = mx + b$ relates to the graph?

a) ☐ it determines the steep of the line
b) ☐ it determines the height of the line
c) ☐ it determines the axis area of the line (in the axis)
d) ☐ it determines the length of the line

2- How does "*b*" in the equation $y = mx + b$ relates to the graph?

a) ☐ It determines the height of the line
b) ☐ It determines the steep of the line
c) ☐ It determines the width of the line
d) ☐ it determines the axis area of the line (in the axis)

3- How can you make a line steeper?

a) ☐ By increasing the *"m"* value
b) ☐ By decreasing the *"m"* value
c) ☐ By increasing the *"b"* value
d) ☐ By decreasing the *"b"* value

4- How can you make a line less steep?

a) ☐ By increasing the *"m"* value
b) ☐ By decreasing the *"m"* value
c) ☐ By increasing the *"b"* value

d) ☐ By decreasing the *"b"* value

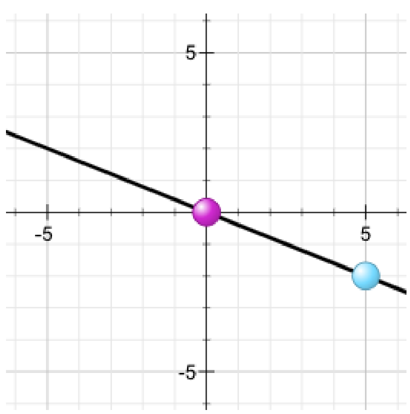
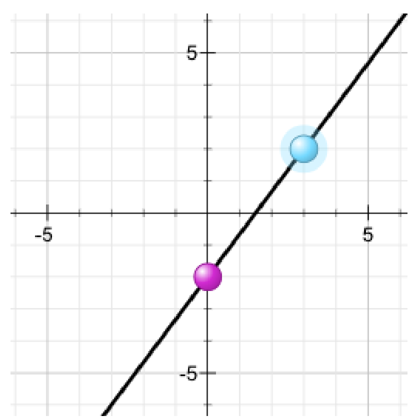
5- How can you shift up a line?

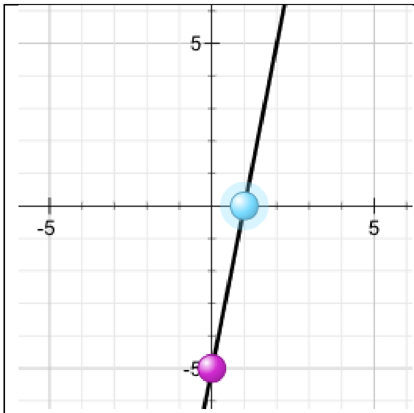
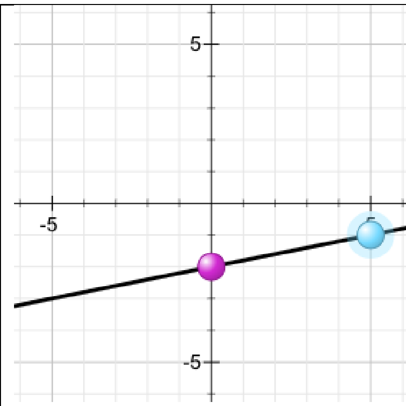
a) ☐ By increasing the *"m"* value
b) ☐ By decreasing the *"m"* value
c) ☐ By increasing the *"b"* value
d) ☐ By decreasing the *"b"* value

6- How can you shift a line down?

a) ☐ By increasing the *"m"* value
b) ☐ By decreasing the *"m"* value
c) ☐ By increasing the *"b"* value
d) ☐ By decreasing the *"b"* value

7- Which line belongs to $y = \frac{1}{5}x - 2$?

a) ☐ 	b) ☐ 
c) ☐	d) ☐

8- What are $\frac{3}{4}$ and *2* in the equation $y = \frac{3}{4}x + 2$, respectively?

a) ☐ Slope line and intercept point

b) ☐ Intercept point and slope line

c) ☐ Direction of line

d) ☐ Height of line

Appendix 3

Digital Game Attitude Scale (DGAS)

The following items examine your attitude toward **Digital Games**. Please read each item and choose one option to determine the degree to which you agree or disagree with it. Please put (X) into the box that shows your answer.

Items	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1- I don't realize how time passes so quickly when I play digital games					
2- I think the benefits of digital games are questionable					
3- I think digital games are waste of time					
4- I think digital games improve hand-eye coordination					
5- Digital games help socialization					
6- I regret the time wasted playing digital games.					
7- I don't enjoy playing digital games					
8- The best way to unwind is to play digital games					
9- Passing a level when playing digital games excited me					
10- It is boring for me to talk about digital games					
11- I make an effort to get reward, trophies, and other gamer strengthening aspects in digital games					
12- I talk about digital games with my friends					
13- I tell my friends about where to find weapons, trophies and other gamer strengthening aspects in digital games					
14- I download recently released digital games on my computer/phone					
15- I play digital games in my possible opportunity					
16- I keep playing digital games until I pass all levels					

17- I complete all tasks and follow all the instructions when playing a digital game					
18-I don't have anything to tell my friends about digital games					

The italicized items are reversed. Items *2, 3, 5, 6, 7, 10, 18*

Appendix 4

Computer Game Attitude Scale (CGAS)

The following items examine your attitude toward **Computer Games**. Please read each item and choose one option to determine the degree to which you agree or disagree with it. Please put (X) into the box that shows your answer.

Items	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1- I am good at playing computer games					
2- Playing computer games is easy for me					
3- I understand and play computer games well					
4- I am skilled at computer games					
5- I like taking courses that use computer					
6- Using computer games in school is a good way to learn					
7- Playing computer games improves my eye and hand coordination					
8- Playing computer games enhances my imagination					
9- I like it when people talk about computer games					
10- I feel comfortable while playing computer games					
11- I am very interested in solving quests/questions/missions in computer games					
12- I always try to solve the current quest/question/mission in the computer game					
13- Playing computer games makes me happy					
14- playing computer games is part of my life					

15- When I have free time, I play computer games					
16- I talk about computer games with my friends					
17- I am not alone in a computer game as I can make friends there					

Appendix 5

Attitudinal Position Scale for Digital Games (APDG)

The following items examine your attitude toward **Computer Games**. Please read each item and choose one option to determine the degree to which you agree or disagree with it. Please put (X) into the box that shows your answer.

Items	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1- Assessment via digital game decreases exam anxiety.					
2- Educational digital games can make learning faster.					
3- Educational digital games help to understand the subject matters easily.					
4- Educational digital games can improve learning.					
5- Educational digital games increase concentration.					
6- In general, educational digital games are beneficial for me.					
7- In general, educational digital games are beneficial for university educational system.					
8- I am concerned my computer gets impaired during playing educational digital games.					
9- I am concerned that my computer may be hacked during playing educational digital games.					

10- I am concerned that the content of educational digital games and my course are not the same.					
11- I am concerned about increasing my internet expenses by playing educational digital games.					
12- I am afraid of losing time during playing educational digital games.					
13- I am concerned educational digital games are not enough for my course learning.					
14- In general, playing educational digital games online are not safe.					
15- In general, I do not believe that educational digital games are beneficial.					
16- I would like to use more educational digital games in future.					
17- I would like to spend more money to buy educational digital games.					
18- I recommend to my friends and classmates using educational digital games.					
19- In general, I am interested in educational digital games.					
20- I prefer to use educational digital games instead of attending the classroom.					
21- I would be happy to take part in a public discussion about educational digital games.					

22- I would time to read and know about educational digital games.					
23- I am likely to stick by my ideas about educational digital games.					
24- I have strong opinions about educational digital games.					
25- There are so many arguments for or against educational digital games; I could be persuaded by any of them.					

26- Please select one of the following options:

a) ☐ Educational digital games should be promoted at the university.

b) ☐ Educational digital games should be opposed at the university.

c) ☐ I am not sure whether educational digital games should be promoted or opposed at university.

d) ☐ I do not care whether educational digital games should be promoted or opposed at university.

27- To what degree did the following elements of educational digital games attract your attention?

	Little	Some	Quite a bit	A lot
A) Mechanical Elements:				
Visual environment				
Automatic scoring				
Device Mobility				
Ubiquity				

B) Game Elements:				
Time of the game				
Game rules				
Points and stages of the game				
Active animations				
Reward and reinforcement emojis (badges)				
C) Content Subject:				
Variety in assessment formats				
Extra information				
Integrate diverse subjects				

28- To what extent do you think the educational digital games have each of the following effects

	No effect	Minor effect	Moderate effect	Major effect
1. Making understanding and learning educational subjects easy				
2. Making subjects authentic				
3. Making subjects hands on				
4. Making the contents usable in everyday life				
5. Reducing stress in learning the content				
6. Engaging students with the content				
7. Making assessment authentic				
8. Increasing learning motivation				
9. Making learning enjoyable				

Appendix 6

Attitudinal Position Scale for the Digital Game of GSI

Attitudinal Position Scale of Graphing Slope-Intercept (GSI)

Items	1	2	3	4	5
1- Assessment in graphing slope-intercept (GSI) decrease exam stress					
2- Graphing slope-intercept (GSI) accelerate learning					
3- Graphing slope-intercept (GSI) help to understand the content easier					
4- Graphing slope-intercept (GSI) help learning to proceed					
5- Graphing slope-intercept (GSI) increase concentration					
6- In general, graphing slope-intercept (GSI) are beneficial for me					
7- In general, graphing slope-intercept (GSI) are beneficial for university education system					
8- I am concerned about my computer during playing graphing slope-intercept (GSI)					
9- I am concerned about hacking my computer during playing graphing slope-intercept (GSI)					
10- I am concerned that graphing slope-intercept (GSI) and my course content are not the same					
11- I am concerned about increasing my internet expenses by playing graphing slope-intercept (GSI)					
12- I am afraid of losing time during playing graphing slope-intercept (GSI)					
13- I am concerned graphing slope-intercept (GSI) is not enough for my course learning					

14- In general, playing graphing slope-intercept (GSI) online is not safe					
15- In general, I do not believe that graphing slope-intercept (GSI) is beneficial					
16- I would like to use more graphing slope-intercept (GSI) in future					
17- I would like to spend more money for graphing slope-intercept (GSI)					
18- I recommend to my friends and classmates using graphing slope-intercept (GSI)					
19- In general, I would like to use graphing slope-intercept (GSI)					
20- I prefer to use graphing slope-intercept (GSI) instead of being in the classroom					
21- I would be happy to participate group talking about graphing slope-intercept (GSI)					
22- I spend time for reading and knowing about graphing slope-intercept (GSI)					
23- I believe in my opinions about graphing slope-intercept (GSI)					
24- My opinions regarding graphing slope-intercept (GSI) are strong					
25- I change my opinions regarding graphing slope-intercept (GSI) easily facing others idea					

26- Please select one of the following options:

a) Graphing slope-intercept (GSI) should be used in the education university system

b) Graphing slope-intercept (GSI) should be forbidden in the education university system

c) I am not sure if graphing slope-intercept (GSI) is either forbidden or used in the education university system

d) I do not care if graphing slope-intercept (GSI) is either forbidden or used in the education university system

27- To what degree the following elements of Graphing Slope-Intercept (GSI) game did attract your attention? Please sign as much as you want.

	Little	Some	Quite a bit	A lot
A) Mechanical Elements:				
Visual environment				
Automatic scoring				
Device Mobility				
Ubiquity				
B) Game Elements:				
Time of the game				
Game rules				
Points and stages of the game				
Active animations				
Reward and reinforcement emojis (badges)				
C) Content Subject:				
Variety in assessment formats				
Extra information				
Integrate diverse subjects				

28- To what extent do you think the Graphing Slope-Intercept (GSI) game has each of the following effects?

	No effect	**Minor effect**	**Moderate effect**	**Major effect**
1. Making understanding and learning educational subjects easy				

2. Making subjects authentic				
3. Making subjects hands on				
4. Making the contents usable in everyday life				
5. Reducing stress in learning the content				
6. Engaging students with the content				
7. Making assessment authentic				
8. Increasing learning motivation				
9. Making learning enjoyable				

Appendix 7

Cover Letter for Professors

Dear Professor,

My name is Mahnaz (Nazy) Shojaee, and I am currently enrolled in Measurement, Evaluation, and Data Science (Ph.D.) at the University of Alberta. As part of my degree requirements, I am conducting research for my Ph.D. thesis about Students' Attitudinal Positions on Digital Game-Based Assessment. To achieve this research, I am seeking your support in recruiting undergraduate and graduate participants nineteen years old and older. This research aims to expand our knowledge of digital game-based assessment's different attitudinal positions and components.

Thus, I am seeking your permission to collect data in your classes. I want to use your entire class session. Your class will be used either as an experimental or a control group to be trained to utilize the digital game of Graphing Slope-Intercept (GSI). This game is a learning and assessment-based game to master the statistical topic named GSI. Before and after using experimental treatment (GSI), I will distribute research packages to students in your classes to be picked up by me before the start of the next class. Each research package contains a letter outlining the purpose of the study, an overview of the student's rights, an invitation to participate and select scales and questionnaires.

Participation in this research is entirely voluntary. Your students do not have to answer questions on the surveys that cause discomfort. All information will be confidential. Quotes from individual surveys may be cited in the thesis and future publications to illustrate a point; however, there is no way to identify the source. The focus is on group results. Survey data will be coded and stored on a secure, password-protected computer. Hard copies of the surveys will be shredded once the data has been entered. Electronic data files will be kept for five years following the thesis defence and then deleted from the computer to allow time for dissemination of the information through conference presentations and published articles.

Should you have any questions regarding this study, please contact me, Mahnaz Shojaee, at mshojaee@ualberta.ca or my thesis supervisor, Dr. Ying Cui, at yc@ualberta.ca.
Suppose you have any questions regarding how this study is being conducted. In that case, you may contact the Faculties of Education, Extension and Augustana Research Ethics Board (EEA-

REB) at the University of Alberta or the Chair of the EEA REB at 780-492-3751. Thank you for your permission to conduct my research project in your class. I hope this research results in a more excellent promotion of digital game-based assessment.

Sincerely,

Mahnaz Shojaee

Ph.D. Candidate, University of Alberta

Appendix 8

Cover Letter for Students

Dear Student **Code #: ………..**

My name is Mahnaz (Nazy) Shojaee, and I am currently enrolled in Measurement, Evaluation, and Data Science (Ph.D.) at the University of Alberta. As part of my degree requirements, I am conducting research for my Ph.D. thesis about Students' Attitudinal Positions on Digital Game-Based Assessment. This research aims to expand our knowledge of digital game-based assessment's different attitudinal positions and components.

To conduct this research, I am seeking nineteen and older undergraduate participants. Participation in this research is entirely voluntary. You do not have to answer any questions on any measures that cause discomfort; all information will be confidential. Participants will either be grouped as an experimental group or a control group. Each student will learn and assess Graphing Slope-Intercept (a statistical subject) through a digital game as an experimental group. There is no participation in using the game for the control group. Both groups will also be given a research package before and after using GSI. Each package contains 1) a cover letter explaining the purpose of the research and participant's rights and 2) short measures of the variables of the research topic.

Quotes from individual surveys may be cited in the thesis and future publications to illustrate a point; however, there is no way to identify the source. The focus is on group results. Survey data will be coded and stored in a secure, password-protected computer at the University of Alberta. Hard copies of the surveys will be shredded once the data has been entered. Electronic data files will be kept for five years following the thesis defence and then deleted from the computer to allow time for dissemination of the information through conference presentations and published articles.

You can choose to participate or not. If you decide to participate, you can withdraw at any time while completing the measures should you change your mind and all materials you have achieved until that point will be shredded. If you choose to withdraw later, you can contact the researcher and provide her with the code number on this letter, and all your data can be removed from the computer and shredded hard copies if they are still available.

If you choose to participate in this research, please follow the instructions and complete all the measures in person or through the below link of Google Drive (Form). Please ask me if you need any clarification regarding any of the questions. In-person type, I will remain in the room until everyone is finished. You can then place the completed measures back in the research package envelope and pass them to me. If you choose to do that by using the link below, please use the link and complete the questionnaires online.

Please keep this letter so you have my contact information for further questions.

https://docs.google.com/forms/d/e/1FAIpQLSc2GoiBZ_77sQODgeECWBzQLNGFuy4qbU2zYHlsH6bsdXf2iQ/viewform

If you have any further questions regarding this study, please get in touch with me, Mahnaz Shojaee, at mshojaee@ualberta.ca or my thesis supervisor, Dr. Ying Cui, at yc@ualberta.ca

Thank you for considering participating in my research project. I hope this research results in a more excellent promotion of digital game-based assessment.

Sincerely

Mahnaz Shojaee

Ph.D. Candidate, University of Alberta

Appendix 9

Table A

Major Indices of Model Fit

Model	Chi-Square	DF	P	SRMR	CFI	TLI	RMSEA
	5451.2	136	.001	.07	.900	.830	.1

Note. Abbreviations: *df*, Degree of Freedom; *P*, Probability value or Asymptotic Significance; SRMR, standardized root mean square residual; CFI, Comparative Fit Index; RMSEA, Root-Mean-Square Error of Approximation

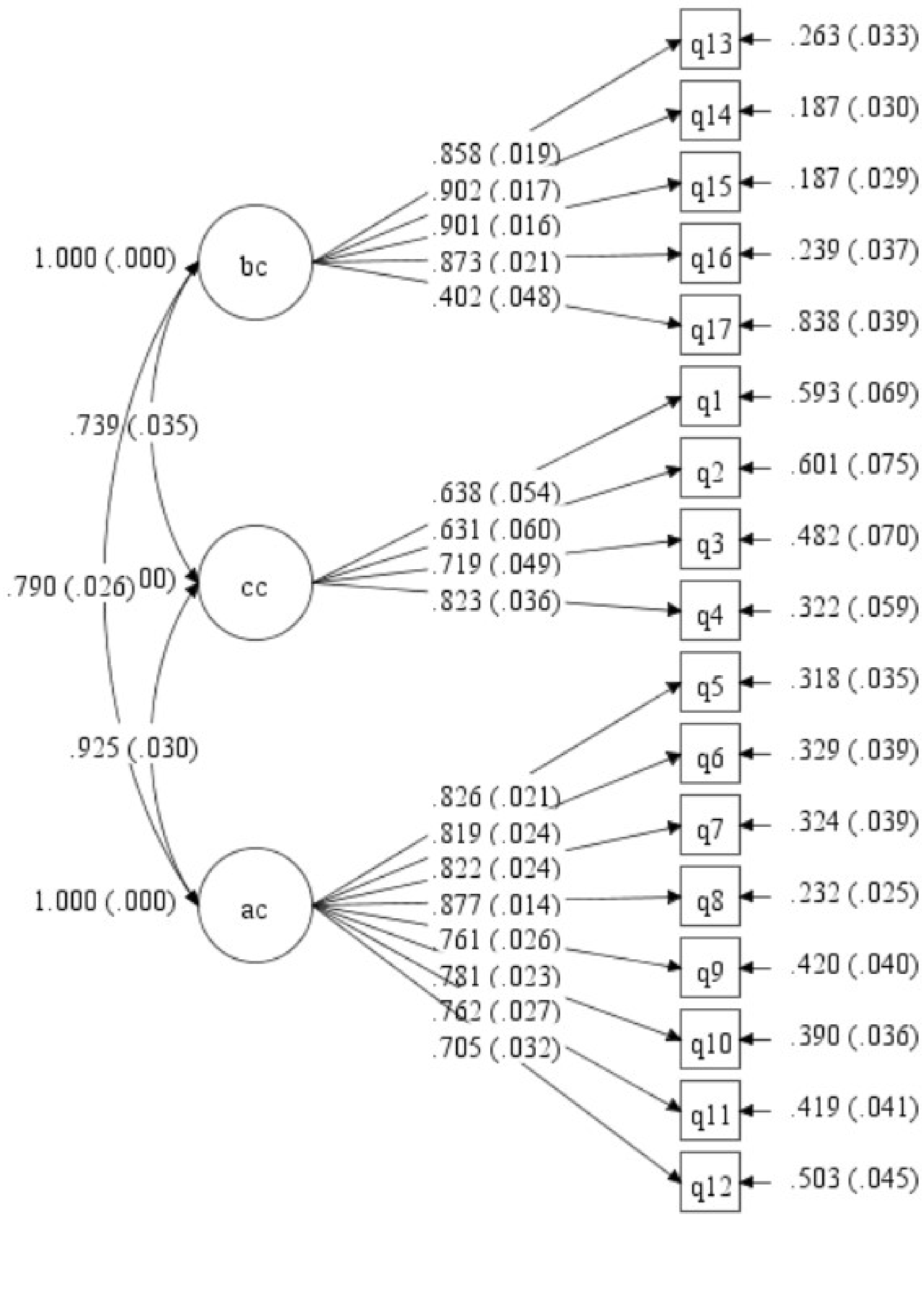
Table B

The Correlation Coefficient of CGAS Components

	Cognitive	Behavioural	Affective
Cognitive	1	0.73**	0.92**
Behavioural		1	0.79**
Affective			1

Figure A

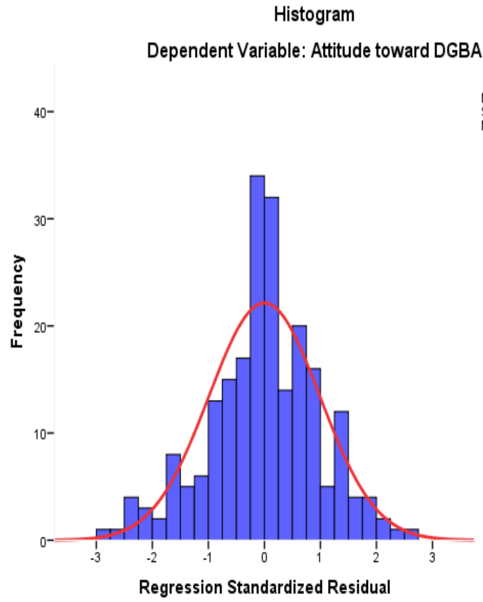
Confirmatory Factor Analysis (CFA) of the Computer Game Attitude Scale (CGAS; N=482)



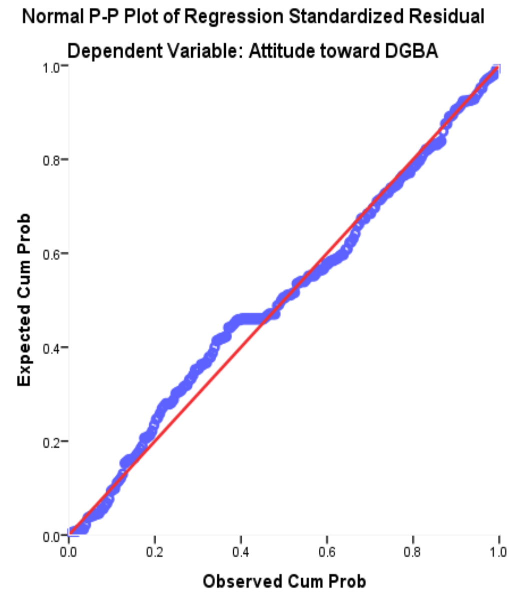
Appendix 10

Figure 16

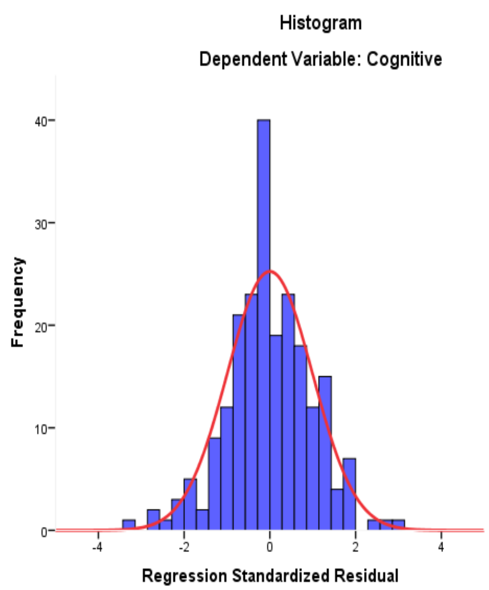
Histograms and Normal P-P Plot of Attitude and its Components in Multiple Regression


Histogram
Dependent Variable: Attitude toward DGBA
Mean = 1.79E-16
Std. Dev. = 0.991
N = 220
Frequency
Regression Standardized Residual

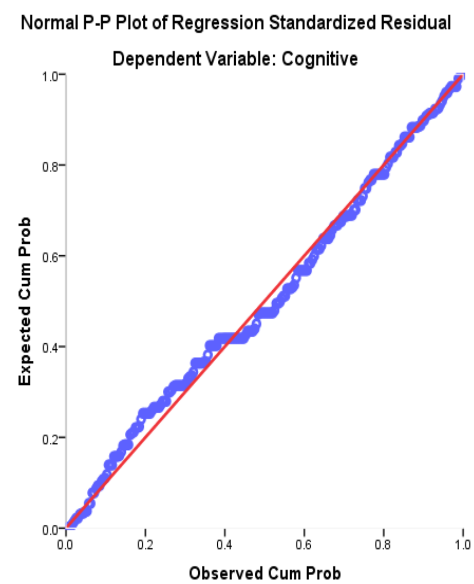
A


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Attitude toward DGBA
Expected Cum Prob
Observed Cum Prob

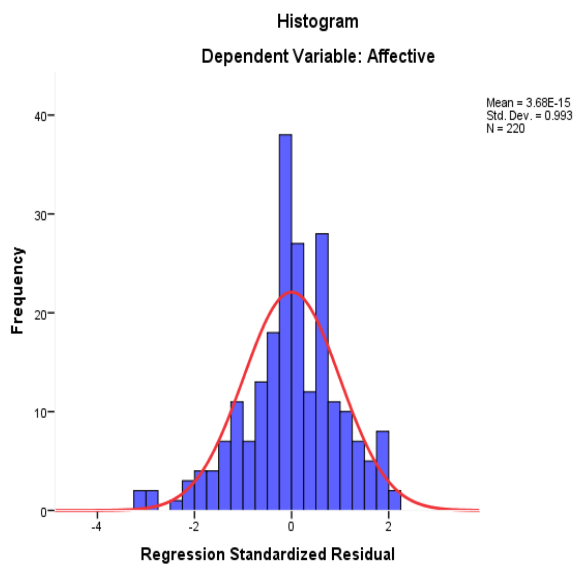
B


Histogram
Dependent Variable: Cognitive
Mean = -8.17E-15
Std. Dev. = 0.993
N = 220
Frequency
Regression Standardized Residual

C

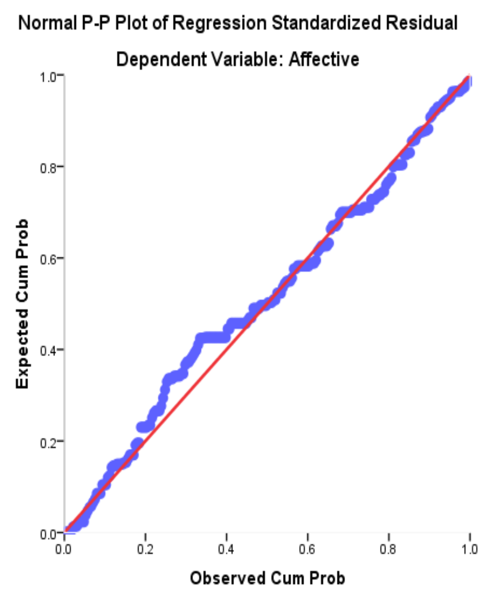

Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Cognitive
Expected Cum Prob
Observed Cum Prob

D



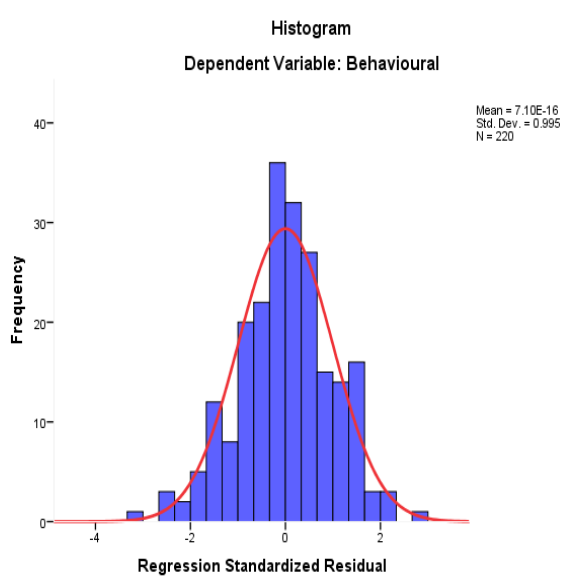
Histogram
Dependent Variable: Affective
Mean = 3.68E-15
Std. Dev. = 0.993
N = 220
Frequency
Regression Standardized Residual

E



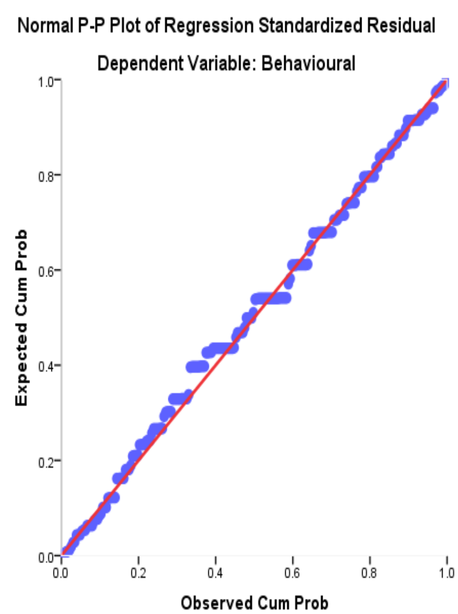
Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Affective
Expected Cum Prob
Observed Cum Prob

F



Histogram
Dependent Variable: Behavioural
Mean = 7.10E-16
Std. Dev. = 0.995
N = 220
Frequency
Regression Standardized Residual

G



Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Behavioural
Expected Cum Prob
Observed Cum Prob

H