PROJECT MANAGEMENT EDUCATION RESEARCH EXCELLENCE WITHIN CYBER-INFRASTRUCTURE ENVIRONMENT

by

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New educational tools and methods have evolved during recent decades as a direct consequence of technology advance. One of these effective pedagogical tools is simulation. The novel features and capabilities (added to simulation applications due to technological advances) have accelerated the pace of growth so that many majors, such as aviation and medical science, have been utilizing simulation as a rich supplementary tool in their curricula. In spite of a strong potential context that exists in construction project management for employing simulation, there are only a limited number of applications developed for educational purposes in the project management area.

This research project explores the effectiveness of using simulation for education of construction project management. To answer the research questions and examine the hypotheses, this study explicates the bases of developing simulation and measuring its effectiveness, and illustrates the design, development, and implementation of two simulation applications: Virtual Interactive Construction Education (VICE) and Project-oriented Educational Research Fostering Excellence in Cyber-infrastructure Teaching (PERFECT). VICE concentrates on the management of a single span bridge project, incorporates project resource constraints, and navigates students through main activities by showing the consequences of each decision they make to achieve the project's goals. Based on the results and feedback from VICE, PERFECT was developed to provide the contents in the project time management area according to the PMBOK standard. The pedagogical value of both applications is determined in two ways: a retrospective self-evaluation of pre and post simulation, and comparison of actual performance of participants before and during simulation. The project's findings affirm the effectiveness of using simulation for

project management education and indicate simulation's role in the increase of students' interest in related subjects. Implementation of VICE and PERFECT, along with their results, promotes the pedagogical perspective toward using simulation and provides a learning basis for future simulation applications in the project management area.

DEDICATION

To my parents, whose calm, patience and constant love sustained me throughout my life, and my wife, whose encouragement and support made my educational journey possible.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Project management in construction engineering and management programs has evolved over the past two decades. Emerging technologies have increased the availability of tools and methods that are being added to the curricula in related programs. One of these emerging technologies is simulation. According to Aldrich (2003) simulations "are tools that allow users to learn by practicing in a repeatable, focused environment" (p. 243).

Construction project management education can be more efficient and comprehensive using simulation. Students navigate through a simulated project, experiencing each activity and exposing various aspects of project management in a limited timeframe. The simulated environment of a project encompasses a variety of project management activities and presents them whenever needed. Simulated environments have not commonly been made available for students of project management due to the time required for continuously tracking a project. The idea of using serious games and simulations has been introduced to construction trainers during recent decades. Although the opportunities that can be brought to construction project management education by simulation are quite vast, it is not yet widespread among construction departments. There is a gap between theoretical concepts and practical knowledge of project management that can be spanned by simulation.

Considering the necessity of using new alternatives in construction project management education, this research utilizes project management knowledge contents and proposes a model for simulation of a project environment using appropriate standards. The foundation of this research is built on project-based learning theories and utilization of simulation for education. This research involves implementing simulations and measuring their effectiveness for project management education.

1.2 PROBLEM STATEMENT

Practitioners in the construction field have not agreed upon the most effective educational contents. McCabe, Ching, and Rodrigues (2000) believe that typical coursework only deals with some theoretical concepts and is not effective enough to empower students to face real-world problems. AbouRizk and Sawhney (1994) explain the inefficiency of traditional construction curricula and urge alternative methods for construction education. Rojas and Mukherjee (2005) are concerned that conventional construction education is no longer able to carry out its mission satisfactorily, and this realization has led various researchers to find new educational alternatives such as gaming and simulation. Examples of gaming and simulation are AROUSAL (Ndekugri & Lansley, 1992), Superbid (AbouRizk, 1993), STRATEGY (McCabe, Ching, & Rodrigues, 2000), VIRCON (Jaafari, Manivong, & Chaaya, 2001), and Virtual Construction Simulator 3 (Nikolić, 2011). Despite the existence of these applications, the lack of adequate simulation applications in construction education, and, more specifically, in project management education, is perceptible. Construction-related programs need to supplement the traditional way of content delivery with simulations and serious games.

1.3 PURPOSE STATEMENT

This study explored the outcomes of two different simulation applications, which were project-based pedagogical models that used construction project management concepts to improve the quality and efficiency of construction students. These applications transformed traditional subject-based lectures of construction project management in construction programs to project-based, virtual, interactive simulations.

The purpose of this study was to develop a simulation application to determine if addition of a simulation aids students in mastering the content of a construction project management curriculum unit. Using different beta tests, this research examined the effectiveness of simulation applications. This research measured the perceived construction project management content knowledge resulting from the simulation and compared it with the participants' actual performance. Perceived content knowledge was measured with a retrospective survey that asked students to rate their level of construction project management knowledge before and after simulations. In order to test the effectiveness of simulation, the construction project management knowledge of participants was measured before and throughout the simulation.

1.4 RESEARCH QUESTIONS

The hypothesis of this research was that the designed simulation applications, VICE and PERECT, were virtual project-based learning tools for construction education at the college level as measured by student engagement and level of construction project knowledge. For this purpose, the research questions were as follows:

- What is the effect of the simulation on participants' perception of project management?
- What is the effect of simulation on the level of the participants' engagement?
- What is the relationship between the actual performance of participants and their perceptions about the content of knowledge gained through simulation?

1.5 METHODS

The study used data extraction (performance recording) and a survey for gathering the data. The performance data were retrieved from pre and post questions, which made it possible to conduct a quasi-experiment and perform the required analyses using t-tests and other statistical tools. All project management materials provided in the PERFECT simulation were based on the Project Management Institute's standard, "Project Management Body of Knowledge" (PMBOK). The survey provided the basis for a retrospective self-evaluation for participants. The self-evaluation results were compared with actual performance. The target subjects of this study were students of construction or related programs.

Two groups of students were selected as the test groups for the VICE simulation: high school students and college-level students. The two groups of students participated in VICE tests separately and the data obtained from each test were analyzed to find if there was any difference between these two groups on each section of simulation.

In order to collect more data and conduct correlation, two groups of students were selected for the PERFECT test. The first group included the students in the CONE 4850 & CNST 4850 Planning/Scheduling/Controls class at the University of Nebraska-

Lincoln. Most of the contents provided in the PERFECT simulation were the course subjects. Despite the fact that the Planning/Scheduling/Controls course and the PERFECT simulation used project planning and scheduling concepts, the presentation of contents was linguistically different. The second group included students in the Introduction to Construction course that is typically being offered in the first year of construction engineering and construction management programs. Therefore, this group of students had no or limited knowledge in project management.

1.6 DEFINITIONS

- Project Management: "the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements" (PMI, 2013, p. 6). Project management is accomplished through the appropriate application and integration of the 47 logically grouped project management processes comprising the 5 Process Groups (PMI, 2013).
- Serious Game: any meaningful use of computerized game/game industry resources whose chief mission is not entertainment (Sawyer, 2007). Zyda (2005) defines serious games as "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" (p. 26).
- Project-Based Learning Method: a teaching approach that engages students in sustained, collaborative real-world investigations. Projects are organized around a driving question, and students participate in a variety of tasks that seek to meaningfully address this question (Coffey, 2008).

- Simulation: *Merriam-Webster online* defines simulation as "something that is made to look, feel, or behave like something else especially so that it can be studied or used to train people."
- Quasi-Experiment: "a best attempt at an experiment when it is impossible, or not reasonable, to meet all the criteria of a true experiment. This type of research is typically identified as being void of randomization of either subjects or treatment and/or the lack of comparison groups" (Bradley, 2009).
- PMI: Project Management Institute (PMI), founded in 1989, is the world's leading not-for-profit professional membership association including 2.9 million professionals around the world in the project, program, and portfolio management professions (PMI, 2014).
- Project Time Management: a set of processes required to manage timely completion of the project including Plan Schedule Management, Define Activities, Sequence Activities, Estimate Activity Resources, Estimate Activity Durations, Develop Schedule, and Control Schedule (PMI, 2013).
- ZNETH: Zero Net Energy Test House, is a 1000-square-foot, two-bedroom, one-bath house built as a caretaker's cottage in Hummel Park, Omaha, Nebraska. The project is a collaborative venture between the City of Omaha, the Durham School of Architectural Engineering and Construction, the College of Architecture, the Peter Kiewit Institute, and several industry partners under the supervision of Dr. James Goedert. ZNETH is used in this research as a sample construction project for simulation purposes.

- VICE: Virtual Interactive Construction Education (VICE) is a project-based pedagogical model that uses cyberinfrastructure tools to improve the quality and efficiency of undergraduate STEM education by transforming traditional subject-based lectures in construction engineering and management programs to project-based, virtual, interactive simulations.

1.7 ASSUMPTIONS

The following assumptions were made regarding this study:

- Participating students in each test group had similar characteristics and understandings of project management and simulation.
- Students participating were motivated to complete the simulation activities to the best of their abilities.
- All respondents answered all survey questions honestly and to the best of their knowledge.
- During this study, participants' gender was not considered as a distinguishing factor.
- The PMBOK standard, which was the basis of this study, covers all project time management topics.

1.8 LIMITATIONS

Due to the relatively small group of participants for the study, as well as the limited time available for performing the simulation application, results may not be generalizable beyond the specific population from which the sample was drawn. This simulation could not be a lengthy application covering a vast detailed area of project time management, and, therefore, the lack of devoted time for completing the whole application limited investigating all educational contents in depth.

1.9 DELIMITATIONS

In order to assure manageability of the collected data, survey instruments used mainly multiple-choice items and did not include open-ended response questions. All questions embedded in the simulation as pre-quiz and in-flow were designed in a way that could be convertible to quantified values. Data were collected during one semester of construction program courses. Pre-simulation knowledge of students may vary and in fact is a hindrance in the generalization of results. Another delimitation of this study is the nature of project management as a soft science. The success of a project manager depends on both technical knowledge and personal characteristics, whereas in this study, only those contents of project management that can be trained were considered. Obviously, this study could not sufficiently discern personal attitudes of individuals. Furthermore, as the PMBOK standard claims, project management is not confined to the construction area. Project management is an interdisciplinary area, which can exist in various fields, but this study used the construction field as a context for training project time management.

1.10 RESEARCH SIGNIFICANCE

Studies documenting the results of using simulation in project management are crucial for introducing new alternatives for education of project management in construction. Only a few studies in construction education can be found that specifically report on the design and implementation of a simulation application. This indicates the lack of simulation presence in project management education. The number of studies conducted on using simulation in construction is not comparable to other fields such as aviation and nursing. Educational simulations are related to a scenario-based learning path, which makes it possible for the users to view the problems from different perspectives. This situation creates an environment in which simulations can be utilized as potentially effective interactive educational tools (Nikolić, 2011). Project time management contents can be effectively presented in educational simulation using a construction project as a basis for showing proper usage of those contents. In this way, the trainable contents of project time management can be transferred from a source to the respective audience, and can also be changed from a series of abstract concepts to practical and objective recipes. This study presents the design, implementation, and results of a project time management simulation for construction students.

1.11 DISSERTATION ORGANIZATION

This dissertation is organized into five chapters as follows:

- Chapter 1: presents background information, problem statement, purpose statement, research questions, methods, definitions, assumptions, limitations, delimitations, and dissertation organization.
- Chapter 2: provides the literature review on simulation and project time management contents.
- Chapter 3: presents a proposed method for designing and implementing a simulated application and other tools used in the experiment.

- Chapter 4: summarizes the data gathered through different tools and reports the results.
- Chapter 5: addresses the conclusion of the study along with future work and suggested recommendations.

2 CHAPTER TWO: LITERATURE REVIEW

Project management is an interdisciplinary area that is offered in different fields such as construction, IT, and business. Training for project management students is shaped within this context. Project management with its tools and methods, as it is known today, emerged after World War II. Lack of material and human resources plus government and managerial endeavors to survive in a highly competitive market led to a focus on optimization. Human, equipment, and material resources could not sufficiently respond to the increasing demands of industry; therefore, improving the management of those resources at different levels in organizations became a potential solution for this problem.

Two main factors for gaining competitive advantage, time and cost, were the criteria for improvement and efficiency methods. Critical Path Method (CPM), Graphical Evaluation and Review Technique (GERT), Program Evaluation and Review Technique (PERT), and Earned Value Management (EVM) are examples of efforts to improve time and cost management. A decade after these improvements, the establishment of project management institutes introduced project management as a profession. Gradually, other aspects of project management have been added. Both academia and industry are training those in the field in concepts. Although project management concepts are embedded in various programs at universities, there are few instances of simulation for project management education.

This chapter reviews the relevant topics to the study including simulation, education, and project management, stating the definitions and scope of the topics.

Educational technological tools, which include e-books, animation, educational games, and simulation, are described. Simulation in education and its weaknesses and strengths are discussed in the second section, and measurement of simulation effectiveness is explained. The third section illustrates the project management organizations, definitions, and standards. The role of simulation in project management education is reviewed, and a summary of the chapter is provided.

2.1 EDUCATIONAL TECHNOLOGICAL TOOLS

New educational tools are being introduced, and existing ones are releasing new versions to make them more user-friendly tools. Technology and education in different fields are intertwined so that education through the traditional methods is becoming obsolete. Technology has empowered instructors in every aspect of their jobs. Numerous tools are becoming increasingly popular and widely adopted in education. The following subsections describe four of the more relevant tools including: e-books, animation, educational games, and simulation.

2.1.1 E-Book

There are different definitions for e-books. Hawkins (2000) defines the electronic form of a book as an e-book while Morgan (1999) believes e-books are a combination of hardware and software that allows the readers to read electronic data using a specially designed device.

Lynch (1999) and Terry (1999) address the need to distinguish between a digital book (the content) and the viewing technology (hardware and software). Sawyer (2002) examines the literature to establish a definition of e-books and discovers that most contemporary definitions are related more to hardware and software (viewing technology) than content. According to Gardiner and Musto (2013), “an electronic book (also e-book, ebook, digital book) is a text- and image-based publication in digital form produced on, published by, and readable on computers or other digital devices. E-books are presented visually or aurally, with the audio book as a precursor to, and limited exemplum of, electronic publishing's potential” (p.271). Sawyer (2002) suggests that when defining e-books both hardware and software issues are more important than a definition in terms of content.

2.1.2 Animation

Animation can be defined as “rapid display of images to create an illusion of movement” (Kuchimanchi, 2013). Luz (2010) believes animation is an action to generate perception of movement (life) in that which is static (inanimate). Metaphorically, animations are cartoons (animation film) in which drawings create a sense of movement, soul, and mind (Routt, 2007). Blair (1994) believes animation is a combination of art and craft, in which various individuals bring their skills to create a collaborative product.

In one study, Mayer and Moreno (2002) state that in designing animation, the theoretical bases and designers’ preference model the design process. They address two main approaches for students learning through animation.

2.1.2.1 Information Delivery Theory of Multimedia Learning

According to Mayer and Moreno (2002), learning involves adding information to one’s memory. Based on this theory, the computer is a system for delivering information to learners, and multimedia presentations should not have a better result than singlemedium presentations. Visual presentations make multimedia presentations more effective.

2.1.2.2 Cognitive Theory of Multimedia Learning

As an alternative idea to multimedia learning, meaningful learning occurs when students mentally construct coherent knowledge representations (Mayer & Moreno, 2002). The cognitive theory of multimedia learning is based on three assumptions: dual-channel assumption, limited-capacity assumption, and active processing. Based on this theory, video channels and audio channels have different methods of processing, and a limited amount of information can be processed at any time through either of those channels. The learner should engage in cognitive processes, such as selecting relevant material and integrating it with existing knowledge, to facilitate learning.

2.1.3 Educational Games

Many terms are frequently used as equivalent to educational games such as serious games, simulation, virtual reality, alternative purpose games, edutainment, digital game-based learning, immersive learning simulations, social impact games, and persuasive games (Sawyer & Smith, 2008). "Serious games" can be defined as educational games in which education (in its various forms) is the primary goal, rather than entertainment. Zyda (2005) defines serious game as "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" (p.26). According to Felicia (2009), a serious game aims "to use new gaming technologies for educational or training purposes. It investigates the educational, therapeutic and social impact of digital games built with or without learning outcomes in mind" (p.6).

The importance of educational games has motivated different organizations to investigate related research. The American Society for Engineering Education calls for scholarly and systematic innovations in engineering education that lead to effective learning practices being substantiated with scientifically credible results (Jamieson & Lohmann, 2009). The National Research Council recommends enhancing STEM education by developing project-based and active-learning approaches that initiate engaging experiences (Bransford, et al., 2005). The National Science Foundation's Blue Ribbon Panel on Simulation-Based Engineering Sciences calls for academia to enhance traditional engineering education by creatively using technology (National Science Foundation, 2006). Squire (2011) suggests that serious games have the potential to transform education. Pellegrino and Hilton (2012) indicate that practical experience cannot be achieved using traditional teaching methods while Young et al. (2012) call for gaming to fill this gap in engineering education. Harz (2009) demonstrates that serious games have a high potential in education; however, few effective games are available. Connolly, Boylea, MacArthura, Haineya, and Boyleb (2012) have concluded that further research is needed to determine the viability of serious games for education after conducting a review of a large and diverse body of literature.

Serious games in primary and secondary education confirm their effectiveness (Clark, et al., 2011; Klopfer, 2008). Some applications at the undergraduate level have shown similar results. Gaming technology was applied to a numerical methods course in mechanical engineering to relate the topics more directly to industry (Coller & Scott, 2009). Warmelink, Bekebrede, Harteveld, Mayer, and Meijer (2012) believe that play is currently spreading throughout innovative and professional environments, and those who are in higher education should pay more attention to it.

2.1.4 Simulation

Simulation can be defined as "something that is made to look, feel, or behave like something else especially so that it can be studied or used to train people" (Merriam-Webster). Walker (2009) reports that for the U.S. Army, simulations were a more effective method of learning when compared with traditional methods. In the medical field, simulations improved surgical skills and safety (Kneebone, 2003), anesthesiology (Abrahamson, Denson, & Wolf, 2004), and laparoscopic and cardiovascular techniques (Issenberg & Scalese, 2008).

Simulation is capable of creating realistic environments for different fields. This strength of simulation is strongly matched and suitable to the training needs of construction programs and can therefore make construction education programs more efficient and comprehensive. A simulated project can navigate students through each activity and show various aspects of a project in a limited time frame. The simulated environment of a project can encompass a variety of construction management activities and present them whenever needed. This potential is, generally, a unique opportunity for the students of a construction management course to practice and learn from simulated construction projects.

2.2 SIMULATION IN EDUCATION

Simulations emerged in education in the late 1950s. Their growth continued into the next decade, although this trend did not keep increasing in rate (Harper, Squires, & Mcdougall, 2000). The advent of new technological tools in multimedia, with new featured graphical software, provided a platform to use contemporary learning ideas in education. Processes that are long, population growth for instance, or short, such as force analysis in 3-D environments, came to be seen as suitable for simulation (Harper, Squires, & Mcdougall, 2000). In addition to time, other important factors for choosing simulated environments in education included cost, level of task difficulty, and risk. Although the use of simulation for education encompasses a broad range of fields, the frequency of simulation application and related research is used more in high-risk fields such as aviation and medical science. Hahn (2010), after conducting a thorough review of the history of simulation in aviation, states that one advantage of using simulation rather than other media is the ability of simulations to increase either the transfer of required skills or the efficiency with which transfer is gained. In a study on the utility of simulation in medical education, Okuda et al. (2009) investigate the role of simulation as an educational tool and reported on the use of simulation in basic science, physical examination, clinical clerkships, and skills training at the undergraduate level; and anesthesiology, surgery, obstetrics, emergency medicine, pediatrics, and critical care at the graduate level of medical education.

Although aviation and medical science are the most frequent users of simulations, other fields have also taken advantage of simulation. Wolfe and Bruton (1994) review the history of business gaming and summarize how "management gaming" evolved to its current state. In a study on simulation in international relations education, Starkey and Blake (2001) review the history of simulation in politics. According to their report, simulations can be utilized as tools to apply decision-making processes at situational points, to help policy makers realize the outcomes of various states, and to assist students in the comprehension of international systems and real-world problems. Wolfe and Bruton (1994) review different computerized entrepreneurship simulations considering playing aspects and environments, and suggested activities to cover the majority of subjects discussed in an entrepreneurship course. Künzel and Hämmer (2006) use a simulation successfully in a research project in a psychology course and report a high acceptance of the simulation by groups of psychology students.

Martens, Diener, and Malo (2008) believe that "game-based training" (their terminology for serious games) requires a game, simulation, and learning aspect in almost equal measures (Figure 2-1).

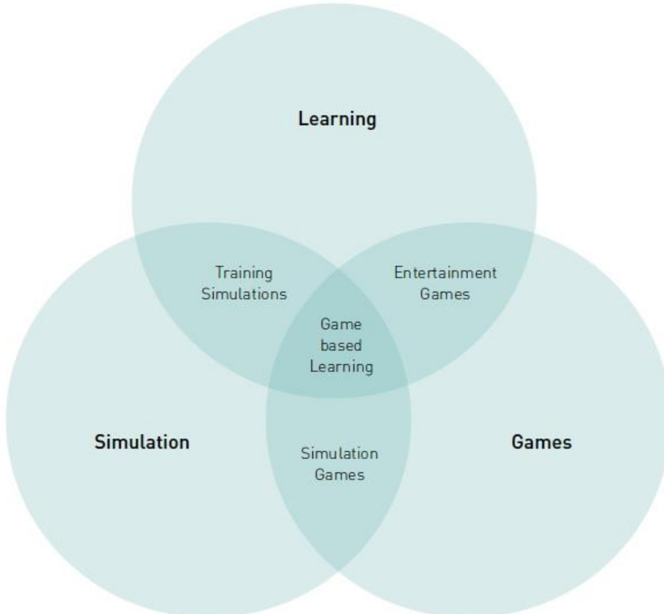


Figure 2-1: Interplay of pedagogy, computer science and games

(*Source: Martens, Diener, & Malo, 2008)*

Despite the frequent use of simulations in education, there is not enough proof to show that simulation can replace traditional educational methods; yet, simulation can be a supplement to conventional techniques. Kiili and Lainema (2008) state that typical educational games are tools to support information transmission, and they do not take advantage of games as interactive media. One main reason for this situation is the lack of integration between simulation design processes and pedagogical elements. Balasubramanian and Wilson (2006) believe that using simulation does not make instructors redundant, and, thus, teachers' subject expertise, understanding of pedagogy comfort level using technology, and easy access to technology are factors to improve the role of simulation in education.

2.2.1 Strengths and Weaknesses

Like any other method in education, simulations and serious games have their own strengths and weaknesses. One of the primary strengths of simulations is that they provide users with practical feedback when designing real-world systems; thus, it would be possible for developers to determine the correctness and efficiency of a design.

Moreover, the contents that will be taught through simulation will be provided in an abstract environment, instead of a real one, and, therefore, the cost of education is decreased. This strength is especially important for education in high-risk fields (Craig, 1996).

Another strength of simulations and serious games is their ability to visually display the consequences of different decisions in a project. Visualization can be done several times with minimum cost, and players can easily see the results of their decisions. Using simulations and serious games as many times as required, regardless of time and location, is another strength.

Simulations and serious games have some weaknesses as well. One weakness is their vulnerability to errors. Any incorrect key stroke has the potential to alter the results of the simulation (Craig, 1996). Another weakness is related to the perception of a simulation. Many people believe what they are doing is engineering only if they can see, hear, feel, and taste the project. This makes simulations and serious games not realistic enough for some people (Craig, 1996). Another drawback of simulations and serious games is their dependence on specific software or hardware. Computer-based tools and specifications of an application may not be compatible with a platform. Another weakness of simulation and serious games is the limited nature of their duration. Because of the characteristics of simulations, they should be accomplished within a relatively short period, and sometimes this hinders the developers from providing enough content or all possible situations in a simulation or serious game. One way to mitigate the risk of time is to presume some regulations and boundaries. There also is not a uniform standard for evaluation. Although, different general methods are defined for measuring the effectiveness of simulations and serious games, there are always some factors specific to each simulation that make it hard to measure the effectiveness of simulations accurately.

2.2.2 Simulation Effectiveness Measurement

Measuring the effectiveness of simulations in educational research is not completely defined and structured. According to Harteveld (2012), "despite a decade of strong interest (if not longer) and explosion of publications and research studies dealing with the value and effects of games, the field is still in dire need of comprehensive, rigorous studies into effectiveness of games – that is studies that go beyond anecdotal, descriptive, or judgmental evidence" (p.10). Although effectiveness can be interpreted in different ways, it can generally be defined as doing the right thing. In this regard, the answer for a question about whether a simulation is effective would be yes or no, whereas the extent that the simulation has achieved its goals is unclear.

Donald Kirkpatrick and James Kirkpatrick (2006) propose a framework to evaluate programs. This framework is modeled on four levels as follows:

Level 1: Reaction

Level 2: Learning

Level 3: Behavior

Level 4: Results

On the first level, Reaction, the way that participants in a program react is measured. On the Learning level, the extent to which participants in a program change their attitudes and enhance their knowledge and skills is measured. The extent to which the behavior of a participant changes is measured on the Behavior level. On the Result level, the final outcomes of participants are measured.

There are four difficulties encountered in measuring the effectiveness of a simulation:

- Having a control group

  Although having a control group in an educational simulation is very difficult, it can validate the results gained by treated subjects.

- Quantifying the performance of participants

  Participants' performances have a qualitative nature; however, finding a logical way to quantify those performances is essential in measuring the effectiveness of the simulation.

- Measuring the engagement level

  Similar to measuring the performance of participants, measuring the level of engagement is another difficulty encountered in assessing the effectiveness of educational simulation. Using standard surveys facilitates the measuring of engagement level.

- Having a normal sample

  Using some statistical tests, like the t-test, requires a normal sample of subjects. This requires a specific number of participants to be accessible for the experiments.

To measure the effectiveness of educational research and make valid claims about treatment variables, educational researchers recommend comparing the group that receives the treatment with another group. Because limitations exist in most programs, it is not practically possible to have two or more groups with different treatments. To overcome these problems, the following methods can be used effectively (Harteveld, 2012):

2.2.2.1 Pre and Post-Questionnaire

Participants can make self-assessments (using Likert items) of their knowledge and attitudes toward the simulation before and after exposure to it. Based on these self-assessments, the learning outcomes could be determined. In addition, some further questions can be asked about topics such as gender, game attitude, and simulation judgment. According to the Kirkpatrick model (2006), on the Reaction level a sheet is used to quantify the reaction. This form should provide the maximum information and take minimum time, and can be taken either at the beginning or end of the program. This form can include sections for comments and suggestions.

2.2.2.2 Pre and Post-Sensemaking Test

Harteveld (2012) defines sensmaking as "a process by which people give meaning to experience or as how people make sense out of their experience in the world" (p.41). In order to determine participants' sensemaking skills, the failure situation should be assessed before and after exposure. Similar to self-assessment, which acts as a proxy of actual cognitive learning outcomes, sensemaking tests are a proxy of sensemaking performance.

2.2.2.3 Game Quiz

After every part of the simulation, participants answer some brief questions to understand how these participants experienced a module and determine if their performance was changed through the simulation. Educational modules can be designed in accordance with the curricula. Questions can be open or closed questions.

According to the Kirkpatrick model (2006), on the Learning level, it is determined what knowledge was learned. For this purpose, one guideline for evaluation learning is to evaluate knowledge by a test related to the content of the program both before and after the program. In addition, using a control group provides better evidence that change has occurred.

2.2.3 Game Data

The performance of each participant results in game data. These game data consist of quantitative data (score, and number of attempts for closed questions) and qualitative data about the time that is taken for each activity of a stage. These data can be extracted and analyzed in comparison with other variables to draw possible correlations.

2.2.4 Pre-existing Measurement Tools

Generally, one way to determine the success of a simulation is measuring differences between pre- and post-levels of self-efficacy, content knowledge, and interest in STEM disciplines. Some pre-existing measurement tools can be used in the assessment process. Results can be examined for differences based on gender, ethnicity, and socio-economic status.

- The Motivated Strategies for Learning Questionnaire (MSLQ) was designed at the National Center for Research to enhance Postsecondary Teaching and Learning at the University of Michigan by Pintrich, Smith, Garcia, and McKeachie (1991), and further developed by VanderStoep and Pintrich (2003) to assess students' motivational orientations and their use of different learning strategies.
- The STEM Semantic Survey can be administered pre- and post-RMT intervention to test for changes in students' interest in a STEM career. Tyler-Wood, Knezek, and Christensen (2011) developed the STEM Semantics Survey as a tool to evaluate students' perception of STEM disciplines and careers. The STEM Semantics Survey is composed of a five-part questionnaire.

2.3 PROJECT MANAGEMENT

The history of project management extends back to over 4000 years ago. Over this long period, project management has produced some phenomenal projects including the Pyramids at Giza, the Parthenon, the Colosseum, the Gothic Cathedrals of Europe, the

Taj Mahal, and the Transcontinental Railroad. These projects were accomplished in a similar way as contemporary projects with the approach of life-cycle analysis. The structure and main elements of project management were used either explicitly or implicitly in these projects (Kozak-Holland, 2011).

However, the new definitions and environment for project management terms emerged in the 20th century around the Second World War and specifically through the mega projects that were required. Project management techniques advanced because of the need for effective management of human resources and materials. Time management was another main factor as a key for success. These circumstances led the business world to adopt project management as a specialized field (Haughey, 2010).

2.3.1 Project Management Organizations

The International Project Management Association (IPMA) was founded in Europe in 1967, as a federation of several national project management associations. IPMA maintains its federal structure today and now includes member associations on every continent (IPMA, 2014).

The Project Management Institute (PMI) was founded in 1969 in the U.S. It offers a range of services to the project management profession such as the development of standards, research, education, publication, and networking opportunities. The PMI is the internationally recognized leader for the project management profession. With more than 440,000 members, its influence extends to nearly every country. It promotes global standards, certification programs, and professional development opportunities for chapters, members, and communities of practice. The most important of these is the

PMP® credentialing that demonstrates the ability to manage projects through experience and education. A recent salary survey showed that certification resulted in higher salaries for project managers (PMI, 2014).

2.3.2 Project Management Standards

There are two main project management standards as a guideline for practitioners: Project Management Body of Knowledge and PRINCE2.

2.3.2.1 Project Management Body of Knowledge (PMBOK)

PMI publishes *A Guide to the Project Management Body of Knowledge* (*PMBOK Guide*), which describes project management practices that are often applicable in most projects. *PMBOK Guide* provides established norms, methods, processes and practices for project management practitioners. Forty-seven project management processes are categorized into 10 knowledge areas. As shown in Figure 2-2 , these include: 1. Project Integration Management, 2. Project Scope Management, 3. Project Time Management, 4. Project Cost Management, 5. Project Quality Management, 6. Project Human Resource Management, 7. Project Communication Management, 8. Project Risk Management, 9. Project Procurement Management, and 10. Project Stakeholder Management (PMI, 2013).

Knowledge Area	Process Group				
	Initiating	Planning	Executing	Monitoring and Controlling	Closing
Project Integration Management	Develop Project Charter	Develop Project Management Plan	Direct and Manage Project Work	Monitor and Control Project Work Perform Integrated Change Control	Close Project or Phase
Project Scope Management		Plan Scope Management Collect Requirements Define Scope Create WBS		Validate Scope Control Scope	
Project Time Management		Plan Schedule Management Define Activities Sequence Activities Estimate Activity Resources Estimate Activity Durations Develop Schedule		Control Schedule	
Project Cost Management		Plan Cost Management Estimate Costs Determine Budget		Control Costs	
Project Quality Management		Plan Quality Management	Perform Quality Assurance	Control Quality	
Project Human Resource Management		Plan Human Resource Management	Acquire Project Team Develop Project Team Manage Project Team		
Project Communication Management		Plan Communications Management	Manage Communications	Control Communications	
Project Risk Management		Plan Risk Management Identify Risks Perform Qualitative Risk Analysis Perform Quantitative Risk Analysis Plan Risk Responses		Control Risks	
Project Procurement Management		Plan Procurement Management	Conduct Procurements	Control Procurements	Close Procurements
Project Stakeholder Management	Identify Stakeholders	Plan Stakeholder Management	Manage Stakeholder Engagement	Control Stakeholder Engagement	

Figure 2-2: Knowledge areas and processes of PMBOK

2.3.2.2 PRINCE2

PRINCE2 stems from an earlier method called PROMPTII and from the PRINCE project-management method, which was initially developed in 1989 by the Central Computer and Telecommunications Agency (CCTA) as a UK government standard for information systems (IT) project management (Kelly, 2008). According to its official website, “PRINCE2 is a de facto standard developed and used extensively by the UK government and is widely recognized and used in the private sector, both in the UK and internationally. It embodies established and proven 'best practice' in project management." PRINCE2 comprises a set of principles, a set of control themes, a process lifecycle, and guidance on matching the method to the project's environment (Murray, 2011).

- Principles

The PRINCE2 principles are the guiding obligations for good practice that a project should follow. These are derived from lessons, both good and bad, that have affected project success in the past and are now available as lessons learned (Murray, 2011). They are as follows:

  - Continued business justification
  - Learn from experience
  - Defined roles and responsibilities
  - Manage by stages
  - Manage by exception
  - Focus on products
  - Tailor to suit the project environment

- Themes

The PRINCE2 also has seven themes, which feature aspects of project management that need to be addressed continually throughout the project lifecycle, including the following (Murray, 2011):

  - Business Case
  - Organization

- Quality
- Plans
- Risk
- Change
- Progress

• Processes

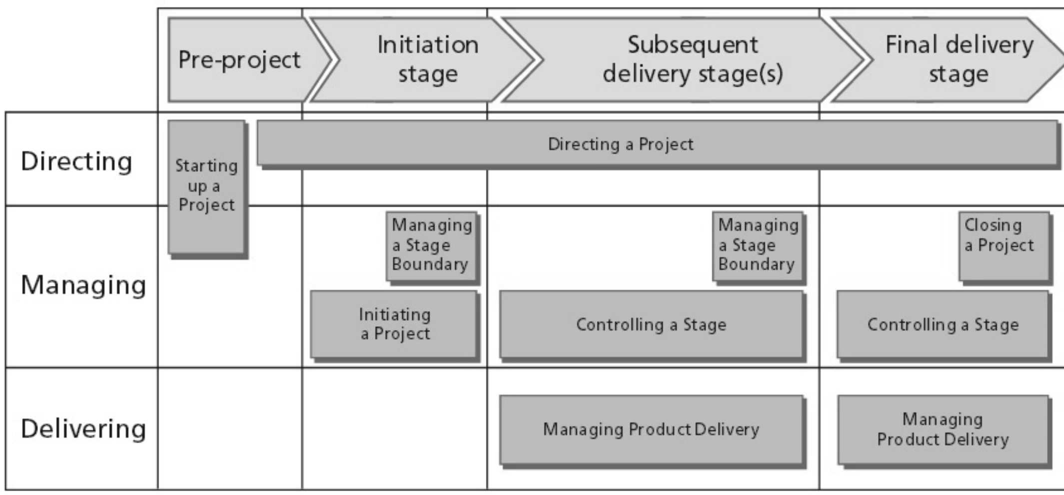


Figure 2-3: Processes of PRINCE2

In addition to principles and themes, there are seven processes for managing a project. Each process is a collection of activities that are required to direct, manage, and deliver a project (Figure 2-3). PRINCE2's processes include the following (Murray, 2011):

- Starting up a Project
- Directing a Project
- Initiating a Project

- Managing a Stage Boundary
- Controlling a Stage
- Managing Product Delivery
- Closing a Project

2.3.3 PMBOK Definitions

The following project management concepts are quoted and defined based on the fifth edition of PMBOK standard.

2.3.3.1 Project

A project is defined as "a temporary endeavor undertaken to create a unique product, service, or result" (PMI, 2013, p. 3). Having a specific beginning and end time shows the temporary nature of projects. When a project achieves its objectives or terminates due to any reason, it can be said that project is finished.

2.3.3.2 Project Management

"Project management is the application of knowledge, skills, tools, and techniques for project activities to meet the project requirements" (PMI, 2013, p. 3).

2.3.3.3 Project Management Processes

PMBOK defines 47 logically grouped project management processes as all processes that may be used through a project lifecycle (PMI, 2013).

These processes are divided into 5 Process Groups including Initiating, Planning, Executing, Monitoring and Controlling, and Closing.

2.3.3.4 Initiating Process Group

Initiating Processes are performed to define a new project or a new phase of an existing project. Initiating Processes obtain authorization to start the project or phase (PMI, 2013) and include Develop Project Charter and Identify Stakeholders.

2.3.3.5 Planning Process Group

According to PMI (2013), Planning Processes are "processes required to establish the scope of the project, refine the objectives, and define the course of action required to attain the objectives that the project was undertaken to achieve" (p. 49). Planning Processes include Develop Project Management Plan, Plan Scope Management, Collect Requirements, Define Scope, Create WBS, Plan Schedule Management, Define Activities, Sequence Activities, Estimate Activity Resources, Estimate Activity Durations, Develop Schedule, Plan Cost Management, Estimate Costs, Determine Budget, Plan Quality Management, Plan Human Resource Management, Plan Communications Management, Plan Risk Management, Identify Risks, Perform Qualitative Risk Analysis, Perform Quantitative Risk Analysis, Plan Risk Responses, Plan Procurement Management, and Plan Stakeholder Management.

2.3.3.6 Executing Process Group

As the name implies, Executing Processes complete the work planned for a project with pre-defined specifications by performing appropriate activities including Direct and Manage Project Work, Perform Quality Assurance, Acquire Project Team, Develop Project Team, Manage Project Team, Manage Communications, Conduct Procurements, and Manage Stakeholder Engagement (PMI, 2013).

2.3.3.7 Monitoring and Controlling Process Group

PMI (2013) defines Monitoring and Controlling Process Group as "processes required to track, review, and regulate the progress and performance of the project; identify any areas in which changes to the plan are required; and initiate the corresponding changes" (p. 49). This process group includes Monitor and Control Project Work, Perform Integrated Change Control, Validate Scope, Control Scope, Control Schedule, Control Costs, Control Quality, Control Communications, Control Risks, Control Procurements, and Control Stakeholder Engagement.

2.3.3.8 Closing Process Group

In order to formally close the project or phase, Closing Processes are performed in projects (PMI, 2013). The Closing Process Group includes Close Project or Phase and Close Procurements.

2.3.3.9 Program

According to PMI (2013) a program is "a group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually. Programs may include elements of related work outside the scope of the discrete projects in the program" (p. 8).

2.3.3.10 Portfolio

"A portfolio refers to a collection of projects or programs and other work that are grouped together to facilitate effective management of that work to meet strategic business objectives" (PMI, 2013, p. 8). Since a portfolio has a broad range of fields, the projects it includes are not necessarily completely related.

2.3.3.11 Project Management Office

A Project Management Office (PMO) is an entity in organizations that is responsible for the management aspects of projects. It centralizes and coordinates activities related to management of projects within organizations (PMI, 2013).

2.3.3.12 Stakeholder

PMI (2013) defines stakeholders as "persons or organizations (such as customers, sponsors, the performing organization, or the public) who are actively involved in the project or whose interests may be positively or negatively affected by the performance or completion of the project" (PMI, 2013, p. 394).

2.3.3.13 Enterprise Environmental Factors

According to the PMI (2013) definition, enterprise environmental factors are factors that directly impact on projects' conditions including culture and structure of organizations, mandatory regulations and standards, surrounding political and economic environments, available resources, and so on.

2.3.3.14 Organizational Process Assets

PMI (2013) defines organizational process factors as "plans, processes, policies, procedures, and knowledge bases specific to and used by the performing organization" (p. 27).

2.3.4 Project Management in Construction vs. Other Industries

Construction projects were one of the foundations of the primitive document prepared as PMBOK in 1987 (PMI, 2002). Since that time, a growing acceptance of project management in various industries has led to broad concepts; therefore, in some cases, general project management concepts do not fully cover present-day project management practices that exist in the world-wide construction industry.

2.3.4.1 Unique features of construction projects

Construction projects have their own unique characteristics. The most important features of them are as follows:

- A number of construction projects do not produce a product; rather they produce a facility that will house the means to make a product such as dams, highways, and parks.
- Geographical factors are main factors of construction projects that affect environment and natural space.
- Construction projects involve many stakeholders and groups, whereas other types of projects do not.
- Construction projects need large amounts of physical resources and tools to move or prepare those resources.

2.3.4.2 Characteristics of the project life cycle

There are as many different variations for project phases as there are differences in the project delivery system. In design-bid-build, the owner or his or her agent prepares a set of plans and specifications, and then a contract is awarded to the best qualified bidder. In design-bid, the owner or agent prepares a set of functional specifications, and then a contractor is hired to design and construct. In the context of project management, the portion of the project that is beyond the construction is not considered as part of the project (e.g. maintenance or operation).

2.3.4.3 Project stakeholders

In addition to the five stakeholders (project manager, customer, performing organization, project team members, and sponsor) that general projects have, every construction project has these two stakeholders as well:

- Regulatory agencies

Federal, state, local or international agencies who issue permissions and control the construction project in some ways.

- General public

Citizens who are affected by the project during its lifecycle.

2.3.4.4 *Organizational structure*

Depending on the size of the contractor or owner, the organization of the project will be projectized, matrix or other types of organization. The management of a construction project sometimes is difficult due to the various stakeholders' viewpoints and agendas.

2.3.4.5 *Key general management skills*

All of the general management activities exist in construction project management including leading, communicating, negotiating, and problem-solving.

2.3.4.6 *Socio-economic influences*

Construction projects have all of the influences that other types of projects might have. Sensitivity and responsiveness to environmental and community concerns may also influence construction projects.

2.3.4.7 *Project management knowledge areas*

Construction projects have 10 knowledge areas in common with other types of projects including Project Integration Management, Project Scope

Management, Project Time Management, Project Cost Management, Project Quality Management, Project Human Resource Management, Project Communication Management, Project Risk Management, Project Procurement Management, and Project Stakeholder Management (PMI, 2013). The processes involved in each of these areas are the same for construction projects.

In addition to common areas, there are four areas that are specific to construction projects (PMI, 2002).

- Project Safety Management
- Project Environmental Management
- Project Financial Management
- Project Claim Management

2.4 PROJECT TIME MANAGEMENT

Project time management is one of the 10 project management areas and aims to provide processes required to manage timely completion of projects. The main purpose of this knowledge area, as its name implies, is to build processes and outputs into the project that assist the project management team to complete the project within a predefined time frame and, therefore, help the team to attain one of the project success indexes.

Time, in almost all projects, is one of three main constraints (time, cost, and quality). Hence, time is considered as an indicator to demonstrate the project success. Despite all of the methods and tools developed to improve project time management, project managers are still suffering from late completion of their projects. Various negative effects can result from the delay, such as increased costs, loss of productivity, and lawsuits between two sides of a contract on a project. Numerous studies have been conducted to identify the quantity of tardiness and root causes in different types of projects. For example, Shrestha, Burns and Shields (2013) showed that the median cost-overrun rates—the difference between the contract bid and final completion cost—for projects costing more than $1 million is 3.24%. They also found that the cost-overrun rate was more likely to occur on larger projects. McGraw-Hill Construction (2011) in its "SmartMarket Report" stated that 84% of its respondents experienced at least one infrastructure project suffering a time overrun. Also, 34% of respondents reported the delays on more than half on their infrastructure projects. In the same report, the average length of delays with overruns reported by respondents was 17% of the total project duration. There are similar reports indicating that one of the main problems from a project management standpoint is managing time. Time management on a project is crucial and is sometimes confused with project management. The importance of time on projects has resulted in various time planning and control tools and methods.

PMI (2013) has devoted one knowledge area to time management and defined seven processes to portray the inputs, tools and methods, and outputs. These processes include Plan Schedule Management, Define Activities, Sequence Activities, Estimate Activity Resources, Estimate Activity Durations, Develop Schedule, and Control Schedule.

2.4.1 Plan Schedule Management

Plan Schedule Management is the first process of the Project Time Management area in which instructions and guidelines for managing, developing, and documenting the project schedule will be demonstrated. Inputs, tools and methods, and outputs of this process are shown in Table 2-1.

Table 2-1: Inputs, tools and methods, and outputs of Plan Schedule Management

Inputs	• Project management plan • Project charter • Enterprise environmental factors • Organizational process assets
Tools and Methods	• Expert judgment • Analytical techniques • Meetings
Outputs	• Schedule management plan

2.4.2 Define Activities

Necessary activities to meet project objectives are defined and systematically documented in Define Activities. Activities are, generally, the lowest level of WBS and are used as units of work to be planned, executed, and controlled. Inputs, tools and methods, and outputs of this process are shown in Table 2-2.

Table 2-2: Inputs, tools and methods, and outputs of Define Activities

Inputs	• Schedule management plan • Scope baseline • Enterprise environmental factors • Organizational process assets
Tools and Methods	• Decomposition • Rolling wave planning • Expert judgment
Outputs	• Activity list • Activity attributes • Milestone list

2.4.3 Sequence Activities

After recognition of activities in the previous process, the relationships between them are identified and documented in Sequence Activities. The factors affecting relationships include the nature of activities, knowledge of best practice, and internal and external interactions with project activities. Inputs, tools and methods, and outputs of this process are shown in Table 2-3.

Table 2-3: Inputs, tools and methods, and outputs of Sequence Activities

Inputs	• Schedule management plan • Activity list • Activity attributes • Milestone list • Project scope statement • Enterprise environmental factors • Organizational process assets
Tools and Methods	• Precedence diagramming method (PDM) • Dependency determination • Leads and lags
Outputs	• Project schedule network diagrams • Project documents updates

2.4.4 Estimate Activity Resources

In Estimate Activity Resources, all resources needed for performing project activities, including human resources, material, and equipment, are identified and quantified. Inputs, tools and methods, and outputs of Estimate Activity Resources are shown in Table 2-4.

Table 2-4: Inputs, tools and methods, and outputs of Estimate Activity Resources

Inputs	• Schedule management plan • Activity list • Activity attributes • Resource calendars • Risk register • Activity cost estimate • Enterprise environmental factors • Organizational process assets
Tools and Methods	• Expert judgment • Alternative analysis • Published estimating data • Bottom-up estimation • Project management software
Outputs	• Activity resource requirement • Resource breakdown structure • Project documents updates

2.4.5 Estimate Activity Duration

The quantity of time units for each activity, identified in previous processes, is estimated in Estimate Activity Duration, considering the estimated resources. Inputs, tools and methods, and outputs of Estimate Activity Duration are shown in Table 2-5.

Table 2-5: Inputs, tools and methods, and outputs of Estimate Activity Durations

Inputs	• Schedule management plan • Activity list • Activity attributes • Activity resource requirement • Resource calendars • Project scope statement • Risk register • Resource breakdown structure • Enterprise environmental factors • Organizational process assets
Tools and Methods	• Expert judgment • Analogous estimation • Parametric estimation • Three-point estimation • Group decision-making techniques • Reverse analysis
Outputs	• Activity duration estimates • Project documents updates

2.4.6 Develop Schedule

Develop Schedule uses different tools and methods to create the optimum sequences of activities and to specify the activities' durations considering the project constraints. The generated schedule model contains scheduled activities, durations, resources and their availabilities, and logical relationships between activities. Inputs, tools and methods, and outputs of Develop Schedule are shown in Table 2-6.

Table 2-6: Inputs, tools and methods, and outputs of Develop Schedule

Inputs	• Schedule management plan • Activity list • Activity attributes • Project schedule network diagrams • Activity resource requirement • Resource calendars • Activity duration estimates • Project scope statement • Risk register • Project staff assignment • Resource breakdown structure • Enterprise environmental factors • Organizational process assets
Tools and Methods	• Schedule network analysis • Critical path method • Critical chain method • Resource optimization techniques • Modeling techniques • Leads and lags • Schedule compression • Scheduling tool
Outputs	• Schedule baseline • Project schedule • Schedule data • Project calendars • Project management plan updates • Project documents updates

2.4.7 Control Schedule

In the Control Schedule process, the status of project progress will be continuously monitored. Any changes in activities will be applied to the project schedule and proper actions will be taken to respond to these changes. Inputs, tools and methods, and outputs of Control Schedule are shown in Table 2-7.

Table 2-7: Inputs, tools and methods, and outputs of Control Schedule

Inputs	• Project management plan • Project schedule • Work performance data • Project calendars • Schedule data • Organizational process assets
Tools and Methods	• Performance review • Project management software • Resource optimization techniques • Modeling techniques • Leads and lags • Schedule compression • Scheduling tools
Outputs	• Work performance information • Schedule forecasts • Change requests • Project management plan updates • Project documents updates • Organizational process assets updates

2.5 SIMULATION IN CONSTRUCTION PROJECT MANAGEMENT

Although there are various opportunities that can be brought to construction management education by simulation, it is not yet widespread among construction departments, and, hence, the huge gap between construction management education and simulated learning methods should be filled by developing relevant applications. Program Evaluation and Review Technique (PERT) and similar scheduling tools have been construction simulations for over 50 years (Rokooei & Goedert, 2015). However, until recently, construction simulations have made little progress. Martin (2000) developed Contract & Construct, a simulation in which five strategies—including quality, morale, time, cost, and balance—were selected for use in teaching an MBA course. Davidovitch, Parush and Shtub (2006) developed the Project Management Trainer (PMT) simulator in which they investigated the role of keeping and reviewing learning history on project management education. They found that using the history mechanism, along with the undo ability, is an effective tool to improve the learning process. A multi-agent framework for situational simulations was later developed by Rojas and Makherjee (2005 & 2006) for general purpose construction. MERIT, developed by Wall and Ahmed (2008), included a blended learning approach. Collofello (2000) implemented a software project management simulator in which lifecycle model comparison, risk management, software inspections, critical path scheduling, and overall planning and tracking were the main objectives of simulation. The Virtual Construction Simulator 3 was a three-dimensional interactive model for creating and reviewing schedules, which showed simulations are perceived as more interesting than traditional teaching methods. The research findings indicated that using simulation resulted in an increase in participants' knowledge in the efficient management of the construction process and resources (Nikolić, 2011). Szot (2013) utilized SimProject, developed by Jeffrey Pinto and Diane Parente at Pennsylvania State University as a project management simulation and concluded that participants' perceptions of project management knowledge and their confidence in using knowledge gained increased after the completion of the simulation. Overall, there are three common characteristics among the studies using simulation for project management education: 1) simulations are introduced as supplementary material for project management courses, 2) PMBOK standard is not used in developing simulation, and 3) self- assessment has been the main method for evaluation of simulation effectiveness.

2.6 SUMMARY

This chapter briefly reviewed the literature related to using educational technological tools, simulation in education, project management, and project time management. In the educational technological tools section, four main types of tools—including E-books, animations, educational games, and simulations—were described. In the next section, the use of simulation in education, strengths and weaknesses, and the methods for measuring the effectiveness were demonstrated. Project management organizations and standards and the most relevant applicable definitions were reviewed in the third section. The fourth section presented the seven processes of the project time management area based on the PMBOK standard. In the last section, the limited number of studies on using simulation for project management education were reported. The methodology for conducting this research is described in the next chapter.

3 CHAPTER THREE: METHODOLOGY

This research project will investigate the effectiveness of two simulation applications in construction project management education. The following research hypotheses will be addressed by this study:

- There is a difference between before and after exposure in terms of knowledge gained for those who participate in these simulation applications.
- These applications can be considered as tools for increasing the level of participants' engagement in project management simulations.
- Actual performance of participants coincides with their perceptions about knowledge gained.

The process that examines these hypotheses is described in this chapter, which consists of two sections: Research Design and Application and Instrument Design. Research Design describes the investigation including independent and dependent variables, their relationship to the hypotheses, participant selection, and quantitative methods. Application and Instrument Design explains the different elements of the application instruments and survey design. It also describes the methods for gathering, compiling, and analyzing the data collected. The correlation between data extracted from instruments and data obtained from applications is shown. The tools used for analyzing the data are explained, and the methods for presenting the results are described.

3.1 RESEARCH DESIGN

Random subject selection with control groups is the most reliable qualitative approach for testing the effectiveness of simulations in education (Nikolić, 2011). Learning is a complex procedure and hard to fully model, and, therefore, it would be difficult to simulate an educational process. Measuring the effectiveness and validity of simulation in education is a major concern of researchers. Gosen and Washbush (2004) show the correlation of performance, validity of simulations, effectiveness of simulations, and experiential exercises as teaching or learning systems. They also state that to have a reliable experimental method, the approach should be efficient in the designed environment and, concurrently, should present a practical way to evaluate student learning.

This study used quantitative methods research design to measure the effectiveness of construction project management education simulation. The research problem was addressed through the lens of Joseph Maxwell's Model of Interactive Approach (2013) by considering how to create coherent and workable relationships among the components of a research design.

Quantitative method research design was used for collecting, analyzing, and combining quantitative data during the research process (Maxwell, 2013). The interactive method research design model relies on the parts of design forming an integrated and interacting whole that includes different components, which interact with others, instead of a linear or one-directional relationship. The interactive model has five components (Maxwell, 2013):

1- Goals: the main purposes of doing the research, the potential intended outcomes of the research, and the practices and policies that will be affected by the study.
2- Conceptual framework: the principles underlying gathering and organizing the data concerning the issues, settings, or people involved in the research; what previous studies have been done; and those studies' conclusions.
3- Research questions: the specific knowledge required to understand the settings or participants; what is missing from the study to reach the research objectives.
4- Methods: explains how the research is conducted, what approaches are used in gathering and analyzing the experiment data. It consists of four categories: established relationships; experiment aspects such as settings, participants, times and places of data collection; data collecting methods; and analysis tools.
5- Validity: ways of validating the results and preventing specious conclusions. It also specifies how the collected data support the experiment objectives.

Figure 3-1 illustrates the interactive method research design model used in this research study (Maxwell, 2013, p. 6). The goals, conceptual framework, and research questions presented in the figure are described in the first part of the chapter. Methods and validity are discussed in the second part of this chapter.

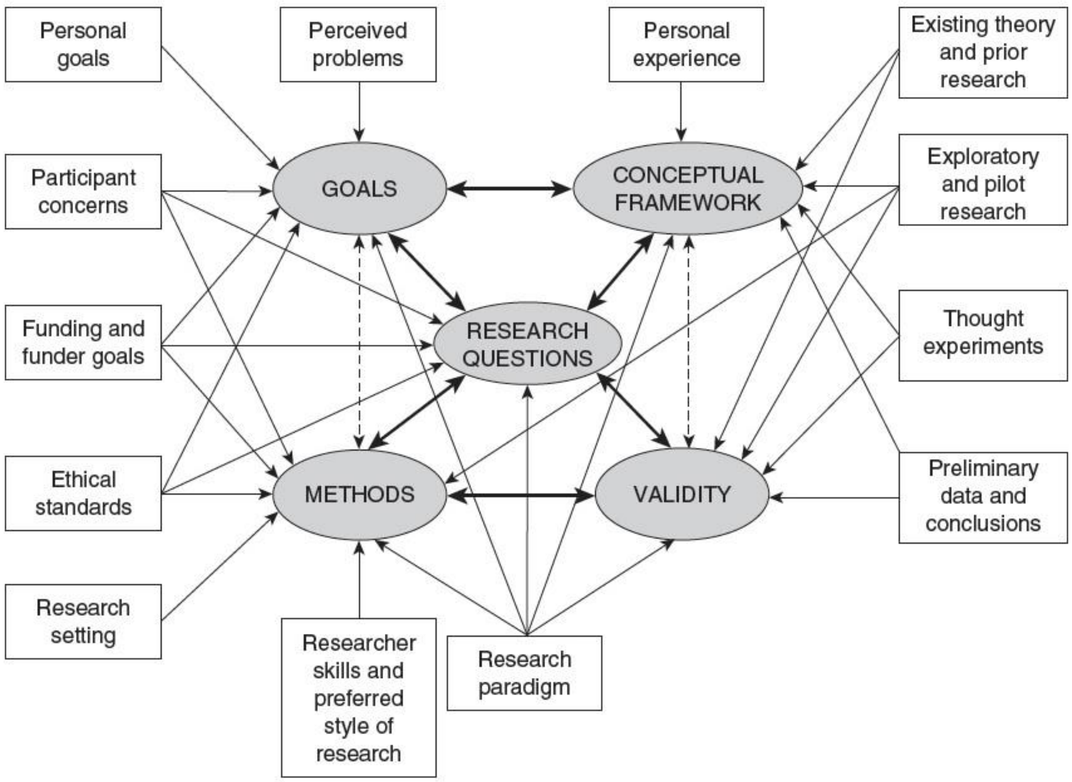


Figure 3-1: Contextual factors influencing a research design (Maxwell, 2013, p. 6)

3.1.1 Quantitative Method

The methodological approach designed to investigate the problem is a quantitative experimental research design. Creswell (2005) defines quantitative research as an inquiry approach useful for explaining the trends and relationships among different variables that might be found in previous studies. In this type of research, the investigator identifies the research problems using narrow questions via instruments. Having analyzed the numeric data, the researcher will be able to interpret the data using prior predictions and research studies and ultimately present them in a standard format. There are six steps in a quantitative research design (Creswell, 2005):

- Describing the research problems
- Reviewing the previous related studies
- Defining the purpose statements, research questions, and hypotheses
- Collecting numeric data
- Analyzing the data and trends
- Reporting the data using a standard format

The main aspects of quantitative research place emphasis on deduction, confirmation, hypothesis evaluation, explanation, prediction, standardized data gathering, and statistical analysis (Johnson & Onwuegbuzie, 2004). The main aim of this experimental study is to identify the effectiveness of using simulation in construction project management education. An experimental quantitative research design was determined appropriate for the research project since it establishes possible causes and effects between the independent and dependent variables.

This research approach allows a single researcher to design the experiment, gather the sample data, and analyze results in a limited time period. Furthermore, it is possible to use inferential statistics because survey data will be collected at the interval level (Punch, 2012).

3.1.2 Research Plan

In the main session of the simulation test, a Pre-Quiz test was administered. Comparison of the results of this test with the results of the actual performance of participants during the simulation showed the effectiveness of both VICE and PERFECT. Forty minutes was considered as the standard time for the test completion, although the Pre-Quiz test was not time-limited. After taking the Pre-Quiz test, participants could start the simulation. Participants logged in to the application using their code. After playing the simulation, participants were automatically directed to the Post-Survey web page to specify their perceptions on knowledge gained.

As explained earlier, the responses of participants on Pre-Quiz and main simulation questions was quantified, using values 1 to 4 as follows:

4: Correct answer in the first attempt

3: Correct answer in the second attempt

2: Correct answer in the third attempt

1: Correct answer in the fourth attempt

The data extracted from both Pre-Quiz questions and corresponding questions embedded in the main simulation were compared and grouped using a two tailed paired samples t test with significance level of $\alpha = 0.05$. A paired samples t test is a tool that is used when one independent variable (cause) is manipulated to show its effect on one dependent variable (effect). This type of t test is used to determine whether the difference in means of the dependent variable between two groups of related scores is statistically significant. In this type of t test, there is no control group (Bui, 2009). A t test was also used to show any difference between the Pre/Post perceptions of participants in five areas of project time management as they reported in Post-Survey. All statistical analyses were done using SPSS v20 and Microsoft Excel 2013.

3.1.3 Variables

The following variables are defined to be measured in this study:

a) Actual performance

b) Perception of knowledge gained

c) Actual knowledge area indicator

d) Work experience

e) Level of engagement

f) STEM interest level

g) Construction interest level

PERFECT was offered to the students of the CNST/CONE 4850 and CNST/CONE 1310 courses as a complementary activity. They voluntarily agreed to play PERFECT. There was no compensation for doing the simulation; however, participants had the opportunity to gain a new perspective on project time management concepts. Thirty participants were selected from each course to play PERFECT.

3.1.4 Population

VICE and PERFECT were aimed at investigating the effectiveness of simulation on construction project management education. Participants of VICE were selected from general high school students and college students in construction programs. Comparison of the high school student group with the college student group allowed investigation of possible effects of previous knowledge on participants' performance. PERFECT participants were selected from the related courses. Among the courses that are offered at the Durham School of Architectural Engineering and Construction at the University of Nebraska-Lincoln, the courses CONE 4850 and CNST 4850 Construction Planning/Scheduling/Controls have similar contents as that of PERFECT. These two courses, plus the graduate courses CNST 8856 and CONE 8856, are typically offered in one section, so the students of this class were selected as the sample of this study. The main outlines of this course include the following:

- Network Diagrams
- Precedence Diagrams
- Determining Activity Durations
- Time in Contract Provisions
- Resource Allocation
- Resource Leveling
- Money and Network Schedules
- Computer Scheduling
- Earned Value
- Impact of Scheduling Decisions
- Short Interval Schedules
- Linear Scheduling
- Computer Scheduling

The complete syllabus of the course CNST 4850 is presented in Appendix A. This course is a core course of both Construction Management and Construction Engineering programs. Students of both programs typically enroll for the course.

In addition, to compare the effect of course contents on participants' performance, another thirty-student group was selected from the combined section of CNST 1310 Introduction to Construction Industry/ CONE 1030 Introduction to Construction Engineering. These two courses are typically offered in one section for the freshman students of the Construction Management and Construction Engineering programs. Due to the educational level, the students of this class do not have any project time management knowledge from the previous construction courses; therefore, this group was an ideal group to compare with the Construction Planning/Scheduling/Controls student group.

The number of students enrolled at the Durham School of Architectural Engineering and Construction during 2008 to 2013 is shown in Table 1 in Appendix B. Also, the number of first-year students enrolled at the Durham School of Architectural Engineering and Construction during 2008 to 2013 is provided in Table 2 in Appendix B. Table 3 in Appendix B shows the number of students in each program for 2013 and 2014.

3.1.5 Ethical Concerns

In order to consider all ethical concerns, approval was obtained from the Institutional Research Board (IRB) of the University of Nebraska-Lincoln prior to launching the research study. According to the IRB's webpage, "the Institutional Review Board reviews research projects that involve human subjects to ensure that subjects are not placed at undue risk, that they give informed consent to their participation, and that their rights and welfare are protected throughout the project" (IRB, 2016).

A certified approved informed consent form was provided to the participants, which clarified the main structure of this research project and affirmed the right of participants to withdraw from the study at any time (Appendix C). A code was given to each participant to identify the relevant data of different tools while the names and other identifying information of participants were unknown to the researchers.

Since the research study deals with factors that specify the effectiveness of simulation in the construction field, it was not expected that participating in this study would have any negative impact on the participants. All collected data was stored on a password-protected computer in a locked office, and transcriptions will be kept no longer than three years beyond the conclusion of the study.

3.2 APPLICATION AND INSTRUMENTATION DESIGN

Two simulation applications, VICE and PERFECT, were designed and implemented as the main instruments of the research project. Although both applications have their own specifications and focus, they define a framework of project management for a certain target group. VICE is a research project, funded by NSF, which began in 2011 and lasted for three years. Based on the findings and lessons learned from VICE, the PERFECT application was designed. The elements of each application are described as follows:

3.2.1 VICE

Virtual Interactive Construction Education (VICE) is a project-based pedagogical model that uses cyberinfrastructure tools to improve the quality and efficiency of undergraduate STEM education by transforming traditional subject-based lectures in construction engineering and management programs to project-based virtual interactive simulations (Goedert, Cho, Subramaniam, & Xiao, 2009; Goedert, Rokooei, & Pawloski, 2013). The purpose of VICE is to overcome the limitations of the traditional subject-oriented learning approach in construction education and directly place students in the full context of running construction projects through a computer generated simulation environment or serious game (Goedert, Pawloski, Rokooeisadabad, & Subramaniam, 2013; Rokooei & Goedert, 2015; Goedert, Rokooei, & Pawloski, 2012). This new pedagogical approach is a holistic paradigm that mimics real life with curriculum topics introduced as needed in a project orientation (Goedert & Rokooei, 2016; Rokooei, Goedert, & Weerakoon, 2014).

3.2.1.1 Pre-Quiz

A Pre-Quiz application is designed for VICE to establish a baseline for construction knowledge level, and, then, compare the results with participants' actual performance. A separate application is designed for this purpose. A code is provided to each participant to log into the Pre-Quiz application. After log in to the Pre-Quiz application, participants are directed through a set of questions similar to those that are provided in the main simulation. This set of questions includes sample questions in excavation, sheetpile, formwork, productivity, and beams areas in the context of a bridge project.

The Pre-Quiz application allows participants to answer each question correctly within three attempts. In addition, there is an "I do not know" button, which is designed in case the participants do not know the correct answer. If a participant cannot answer a specific question after three tries, the application automatically directs the participant to the next question. Therefore, four possible situations for a specific question may occur:

1) If the participant answers the question in the first attempt, then the score for that question would be 4.
2) If the participant does not select the correct answer, a message will pop up and alert the wrong choice, so the participant can try a second time. If a correct answer is provided by the participant, the score would be 3.
3) If the participant again answers incorrectly, another alert message will be shown, and the application will allow the participant to try for the last time. If the participant answers correctly, the score for that questions would be 2.
4) In case the participant cannot reach the correct answer for a specific question, the application directs the participant to the next question. In this case, the score would be 1.

After finishing the Pre-Quiz, the score of each question, each part, and total will be readily available to be saved and shown. The computer-based Pre-Quiz application provides a test situation similar to the VICE application for the participants.

Figure 3-2 shows a screenshot of the Pre-Quiz application. The score gained for each question will not be shown in the Pre-Quiz application. Not revealing the scores helps to prevent any influence on participants and shows their current knowledge of project time management before playing VICE.

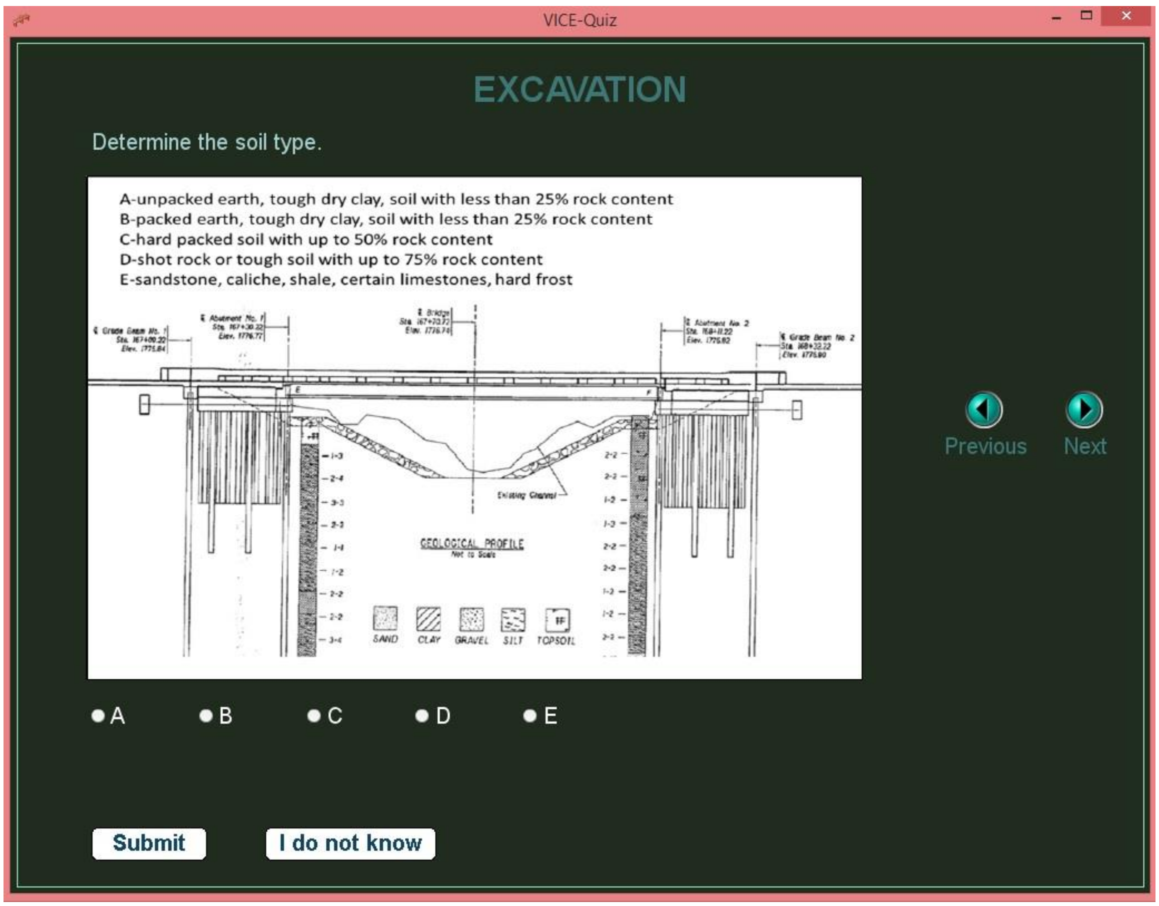


Figure 3-2: VICE Pre-Quiz sample question

3.2.1.2 Main Simulation

VICE is a game-based simulation platform to facilitate collaborative and competitive project-based student learning of construction scenarios. The main simulation provides a rich learning experience by enabling students to interactively find solutions to construction problems posed by domain experts. Problems posed by the experts support several construction-specific parameters such as governing resources, personnel, and time, and demonstrate multiple solutions. Students learn by engaging in problem-solving sessions leading to optimal, sub-optimal, and infeasible solutions. Players sign in with a user name and password associated with demographic information. The game resides locally and transmits player performance data real-time to a SQL-type database using a client-server connection. The platform explicitly supports several pre-programmed student learning modes and seamlessly integrates them with problem-solving to enable solution discovery by guiding user interactions. Game-based models allow self-evaluation by providing incentives and penalty scores for optimal, sub-optimal, and infeasible solutions.

VICE allows students to gain experience in building a single span bridge project. It is developed using Adobe Director, a multimedia application authoring platform, which can be used to create powerful, rich applications on both web and desktop. The interface consists of many modules including video, audio, and user-controlled 3D content. The 3D content and videos for VICE are created using Autodesk 3DS Max and Google SketchUp. Players establish a username that is associated with demographic information and authentication details. The demographic information includes personal, educational and work experience data. The username and demographic information are associated with data automatically collected during game play. These are securely stored in the back-end server using the integrated SQLite3 database. The SQLite3 is an embedded SQL database engine and does not require a separate server process unlike most other SQL databases.

Game play instructions, as well as other interactions, are provided with voice dialogues. For instance, in the first stage of VICE, the player is asked to select the correct order of the work breakdown structure. Upon successful completion, the player advances to the next stage, which requires equipment, material, and personnel choices necessary to complete each of the construction activities.

The framework underlying VICE is powerful and unique in terms of its use for simulation-based construction education. It uses scalable deductive synthesis (Lowry & Subramaniam, 1998) to formulate situation-specific solutions by using automated reasoning techniques (Kapur & M. Subramaniam, 1996) on domain facts and fact components codified using first-order logic extended with arithmetic and recursion.

3.2.1.2.1 Guided Solution Discovery

Each learning experience is modeled as a problem-solving activity in which a user is asked to reach a goal situation from a given initial situation. A solution to a problem is a pre-determined sequence of situations formed by composing the available fact components. Solutions are compiled into a sequence of user interactions to form actionable solution plans. Several solutions and solution plans are feasible for a given problem and are incrementally created and maintained in each problem-solving session (Goedert, Cho, Subramaniam, & Xiao, 2009). In each problem-solving session, feasible (potentially partial) solutions are identified by the learning engine using the given initial and goal situations, and the corresponding plans are created. The solution plan is then transformed into a replay capsule by annotating each user interaction in the plan with instructional attributes such as rationale, pitfalls, and rollback to integrate the learning modes (supervised, unsupervised, and reinforced). The solution plan is then used to provide solution discoveries driven by learning mode. Actionable solution plans and the replay capsules are communicated to the evaluation/guidance engine to assign scores to the interactions in these plans and to rank plans.

3.2.1.2.2 Game-based Problem Solving

Starting from an initial situation, a user performs actions by interacting with the system to transition to the next situation. User actions in each situation are evaluated by the evaluation/guidance engine by comparing them to existing evaluated actionable solution plans to create scored situations. These solutions are then communicated to users with explanations. Re-planning is performed whenever user actions deviate from existing solution plans.

3.2.1.2.3 VICE Domain Expertise

Three critical methodologies for the engineering profession include the integration of visualization, computation, and analysis. VICE provides realistic simulation experiences integrating the three critical methodologies. The interconnectivity required to integrate module content with preceding and succeeding materials requires accurate and extensive domain expertise. Role-play is a motivating factor to immerse learners into complicated topics that are hard to comprehend with factual knowledge (Šisler, Brom, & Slavík, 2008). Domain expertise provides the educational material, the construction process knowledge, and the logic for the platform described in the previous section. VICE simulations include real video, animations, or Internet links as necessary. The total cost of the project reflects the time and cost associated with a limited number of player options. Practical knowledge is only provided through trial and error, consultant inquiry, or educational queries.

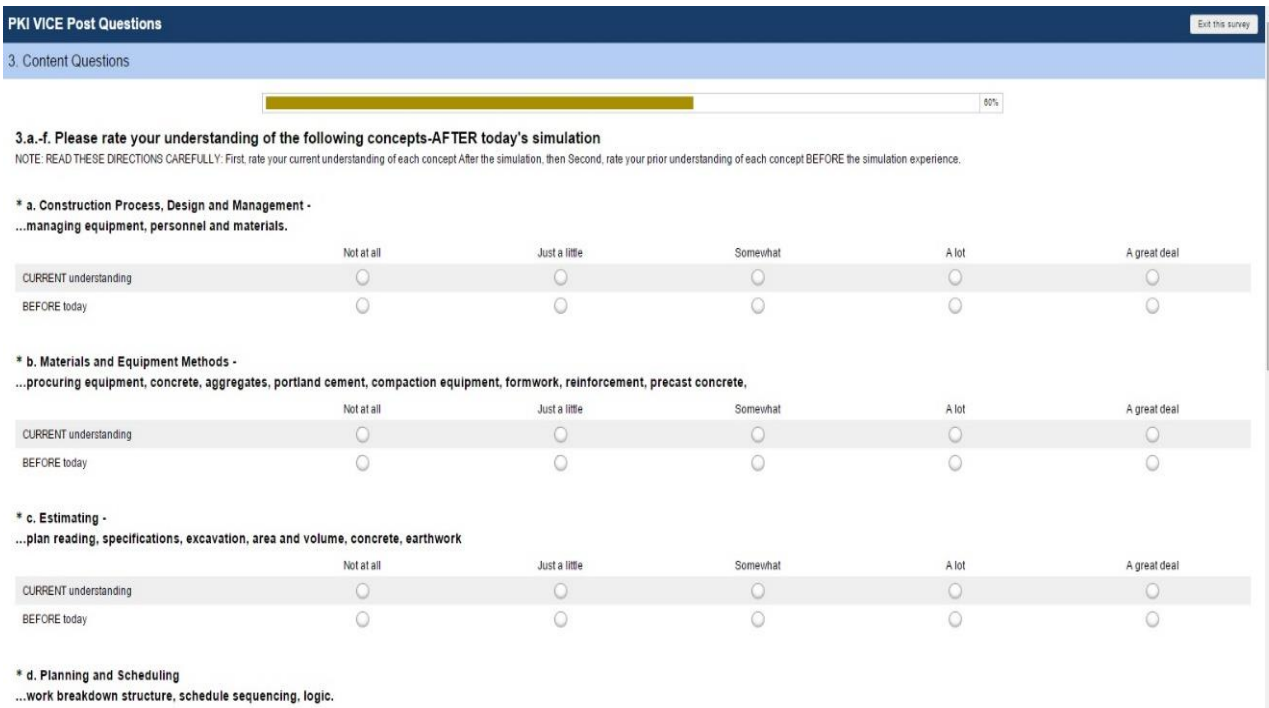
The goal of a VICE module player is to finish a project at an optimal cost and duration. Players are required to make scheduling, equipment, and personnel decisions that will be reflected in the cost and duration. A decision could be optimal, less than optimal, or infeasible. Selections initiate real video of actual construction, web-based training, and/or animations relevant to the current phase of construction. A less-than-optimal choice may result in an increased price and/or duration. A virtual consultant is available to provide guidance at each step through the simulation at an additional cost to the project. An infeasible selection requires the use of the consultant before continuing. Educational lessons are embedded throughout the program, and users can click on objects, such as the excavator, without penalty to access more educational information.

3.2.1.3 Post-Survey

After finishing the main simulation of VICE, participants are directed to an Internet-based survey. A Likert-scale questionnaire, developed by the researcher, is used to collect information. Data are collected by a series of questions asking the participants to rate various statements on their perceptions using simulation on a 5-point scale. The scale ranges from 1 (strongly disagree) to 5 (strongly agree). The Post-Survey has five sections including demographic, interests in STEM, evaluation of pre and post situations, opinion questions, and open-ended feedback. In the STEM section, participants rate whether their interests had increased after playing the simulation. In the next section, participants rate their pre and post situations in five areas on a five-level scale, as shown in Figure 3-3. These five areas include:

a. Construction Process, Design and Management
b. Materials and Equipment Methods
c. Estimating
d. Planning and Scheduling
e. Cost Analysis and Control

The data captured via this survey are used in a paired sample comparison to show any significant differences between pre and post situations. The next section covers some questions on the use of simulation in construction programs. An open-ended feedback section ends the survey.


PKI VICE Post Questions

Exit this survey

3. Content Questions

60%

3.a.-f. Please rate your understanding of the following concepts-AFTER today's simulation

NOTE: READ THESE DIRECTIONS CAREFULLY: First, rate your current understanding of each concept After the simulation, then Second, rate your prior understanding of each concept BEFORE the simulation experience.

* a. Construction Process, Design and Management -
...managing equipment, personnel and materials.

	Not at all	Just a little	Somewhat	A lot	A great deal
CURRENT understanding	○	○	○	○	○
BEFORE today	○	○	○	○	○

* b. Materials and Equipment Methods -
...procuring equipment, concrete, aggregates, portland cement, compaction equipment, formwork, reinforcement, precast concrete,

	Not at all	Just a little	Somewhat	A lot	A great deal
CURRENT understanding	○	○	○	○	○
BEFORE today	○	○	○	○	○

* c. Estimating -
...plan reading, specifications, excavation, area and volume, concrete, earthwork

	Not at all	Just a little	Somewhat	A lot	A great deal
CURRENT understanding	○	○	○	○	○
BEFORE today	○	○	○	○	○

* d. Planning and Scheduling
...work breakdown structure, schedule sequencing, logic.

Figure 3-3: A sample screenshot of VICE Post-Survey

3.2.2 PERFECT

In order to measure the variable and quantify the results of proposed simulation, three instruments were implemented: Pre-Quiz, Post-survey, and PERFECT.

3.2.2.1 Pre-Quiz

A computer-mediated Pre-Quiz is designed for this study. A code is provided to each participant to log into the Pre-Quiz application. An advantage of the study is that the questionnaire causes no apparent risk to participants because the design of the experiment assures participants of their rights to anonymity and privacy.

After a log in to the Pre-Quiz application, participants are directed through the questions section. This section includes 40 questions categorized in eight parts including: general definition of project management, project time management processes, plan schedule management, define activities, sequence activities, estimate activities resources, estimate activities duration, develop schedule, and control schedule.

Pre-Quiz questions are selected from sample preparation questions for PMP certification. Using the standard test provides more validated questions. In order to receive the PMP certification, applicants with ample knowledge of project management are required to take a 200-question exam of different areas of the PMBOK standard.

The results of the Pre-Quiz establish a baseline of project management knowledge. The results are compared to the actual performance of participants to show whether there is a significant difference between the before and after simulation exposure. Pre-Quiz questions are multiple choice with four possible answers. In addition to the four possible answers, there is an "I do not know" button, which is designed in case the participants do not know the correct answer. The application allows the participants to try to answer a question correctly within three attempts. If a participant cannot answer a specific question after three tries, the application automatically directs the participant to the next question. There are four possible outcomes for a specific question:

1. If the participant answers the question in the first attempt, then the score for that question is 4.

2. If the participant does not select the correct answer, a message pops up and alerts the wrong choice, so three possible answers remain to be selected.
3. If the participant answers the question in the second attempt, then the score for that question is the same situation as possibility 2. The procedure is repeated again, and the participant selects the correct answer among the remaining two possibilities.
4. After the third wrong selection, only one choice remains, and consequently the participant has one possible answer to select.

After finishing the Pre-Quiz, the score for each question, each part, and total is readily available to be saved and shown. The computer-based Pre-Quiz application provides a test situation similar to the PERFECT application for the participants.

Figure 3-4 shows a screenshot of the Pre-Quiz application. The score gained for each question is not shown in the Pre-Quiz application. It helps to prevent any influence on participants and shows their current knowledge of project time management before playing with PERFECT.

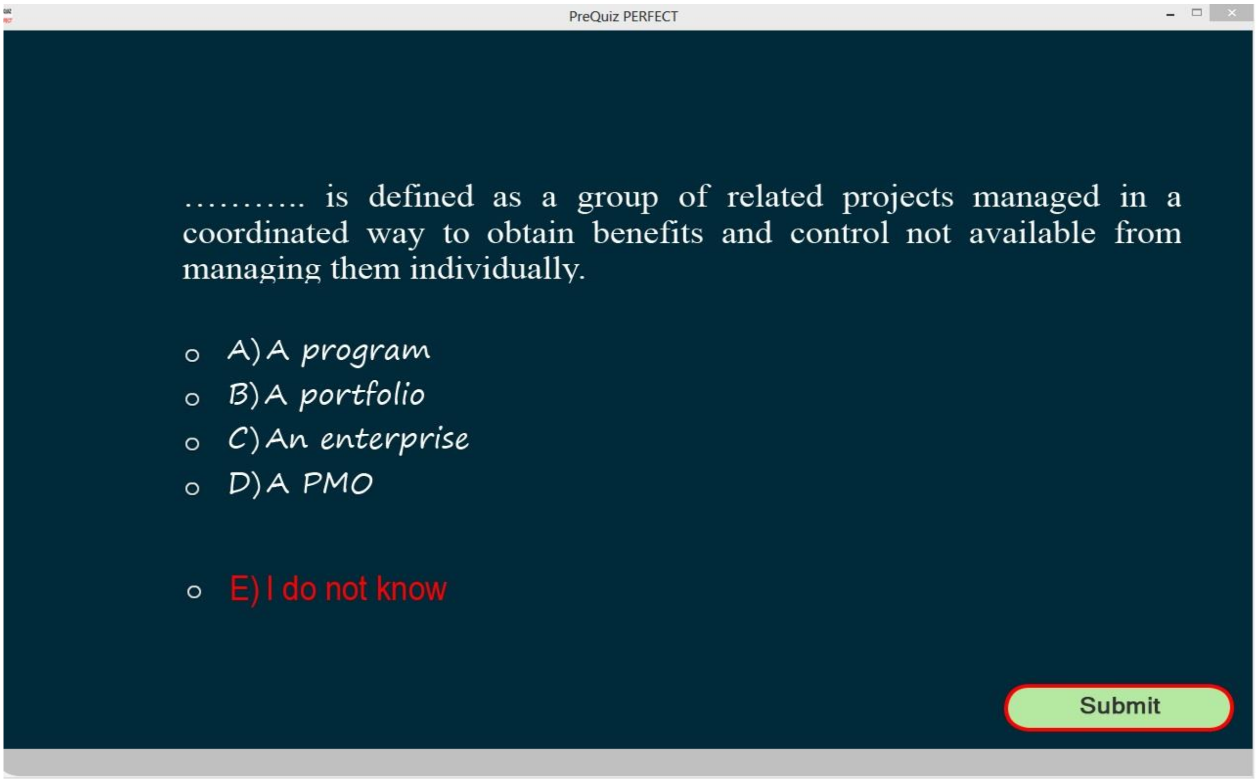


Figure 3-4: A screenshot of Pre-Quiz application

Main Simulation

PERFECT is the intervention being evaluated in this study. It includes education simulations of project time management for a construction project. The education simulation consists of eight chapters. Each chapter contains two types of materials: educational modules and interactive contents.

3.2.2.1.1 Educational Modules

Educational modules provide the theoretical basis of project time management topics. Contents in each educational module in each chapter correspond with the PMBOK guide section, explained in Chapter 2. They are split into eight educational modules:

- Chapter 1: General definition of project management

  This chapter begins with a brief history of project management and current major agencies in the professional field. Then, the definition of general and basic terms in project management – such as project, program, portfolio, project management processes, project management office (PMO), project stakeholder, and sponsor – are presented. All definitions are quoted and explained based on the PMBOK standard.

  After finishing this chapter, players are directed into the first section of knowledge evaluation and should answer a few questions assessing their understanding of project management.

- Chapter 2: Project time management processes

  This chapter provides definitions of project time management and its processes.

- Chapter 3: Plan schedule management and define activities

  This chapter presents the concept of work breakdown structure (WBS) in projects and a few related rules to define the WBS. Then, the definitions of milestone and milestone plan are explained.

- Chapter 4: Sequence activities

The process of defining relationships among the project activities is presented in this chapter. Like other processes, the inputs, tools and methods, and outputs of sequence activities processes are presented. Main inputs of this process – including activity list, activities attributes, and milestone list – are outputs of the previous process, define activities. The main tools and methods of this process are precedence diagramming method, dependency determination, applying leads and lags, and, finally, sequence activity output in project schedule network diagrams. Figure 3-5 shows a view of an educational module for a precedence diagram.

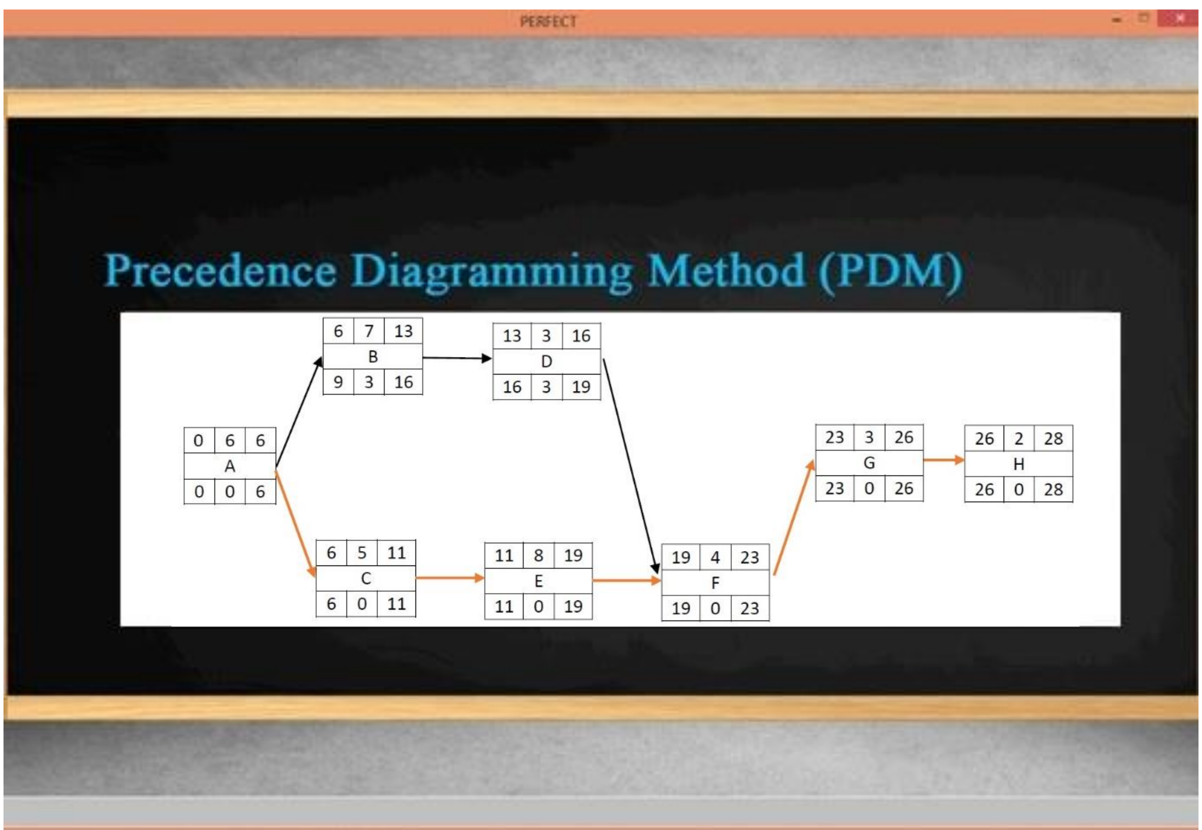


Figure 3-5: Sequence activities educational module

- Chapter 5: Estimate activities resources

This chapter contains a few terms in estimate activities resources process including enterprise environmental factors, organizational process assets, resource calendars, bottom-up estimating, and resource breakdown structure (RBS).

- Chapter 6: Estimate activities duration

Definition, inputs, methods, and outputs of the estimate activities duration process are presented in this chapter. Expert judgment, Analogous estimating, Parametric estimating, Three-point estimates, and Reserve analysis are explained as the common tools in duration estimation.

After finishing this chapter, participants are directed to the next set of knowledge evaluation. They can navigate through different chapters and look over the materials they need to review.

- Chapter 7: Develop schedule

This chapter provides the material to create a critical path of a project and calculate earliest time, latest time, duration, total slack, and free slack of each activity within a project network. The concepts of fast tracking and crashing are also presented in this chapter.

- Chapter 8: Control schedule

This chapter briefly outlines the inputs, methods, and outputs of the control schedule process and explains each of them briefly.

The score, which is shown on the screen, acts as an indicator for the evaluation of participants' responses to the questions. Having finished this chapter, participants are directed to the last set of questions, which cover the contents of the last two chapters. In addition, three questions from previous chapters are repeated again to show any discrepancy between the results.

3.2.2.1.2 Interactive Contents

In order to create an interactive environment, a number of elements have been added to each chapter. These elements provide more practice on the main subjects of each chapter and, therefore, establish an indicator for the quality of the participants' performance. In addition to the score, an Available Fund indicator shows the amount that a participant has used it to get help from the simulation in solving a problem.

The subject of interactive activities varies in respect to the subject of the chapter. For example, in Chapter 3, define the activities, participants need to complete a WBS of a residential project. The related videos and pictures show the correctness of choices in building the WBS.

Figure 3-6: ZNETH project

A real residential project (ZNETH) is used as the source of 3d files, real videos, and pictures. As necessary, related files of the ZNETH project are included in interactive elements. Figure 3-6 shows a view of the ZNETH project.

3.2.2.2 Post-Survey

The participants are directed to an Internet-based assessing instrument called Survey Monkey after finishing the main simulation application (PERFECT). This online survey facilitates administering the Post-Survey to the participants. One of the advantages of using an Internet-based survey tool is the quick extraction of the results with a high reliability.

A Likert-type scale questionnaire, developed by the researcher, has been used to collect information. Data are collected by a series of questions asking the participants to rate various statements on their perceptions using simulation on a 5-point scale. The scale ranges from 1 (strongly disagree) to 5 (strongly agree). The Post-Survey has four sections. The first section contains demographic questions including gender, age, major, education level, and project management work experience. The second section, interest questions, includes questions about previous knowledge of project management, previous experience with virtual learning, and rating the participants' interest in project management and construction as a result of the simulation. The third section contains questions on content. The main part of this section is a self-evaluation of participants about their knowledge gained through the simulation. Participants rate their knowledge in the following areas comparing their perception of those areas before and after playing the simulation. The areas for self-evaluation are as follows:

a) Project Integration Management (general definitions of project management such as project, program, portfolio, etc.)
b) Plan Schedule Management, Define Activity Process (activity definition, WBS, milestone, etc.), and Sequence Activity Process (lag, lead, precedence diagramming method, dependencies: SS, FF, SF, FS, etc.)
c) Estimate Activity Resources Process (bottom-up estimation, top-down estimation, etc.) and Estimate Activity Duration Process (three-point estimation, parametric estimation, expert judgment, analogous estimation, etc.)
d) Develop Schedule (drawing CPM, fast tracking, crashing, etc.) and Control Schedule (control schedule inputs, tools and outputs, etc.)

e) Project Cost Management (earned value management, forecasting, to-complete performance index -TCPI-, etc.)

Project cost management is not covered in the simulation, but is asked in area e for content validity and test-retest reliability. Figure 3-7 shows a screenshot of one these questions:

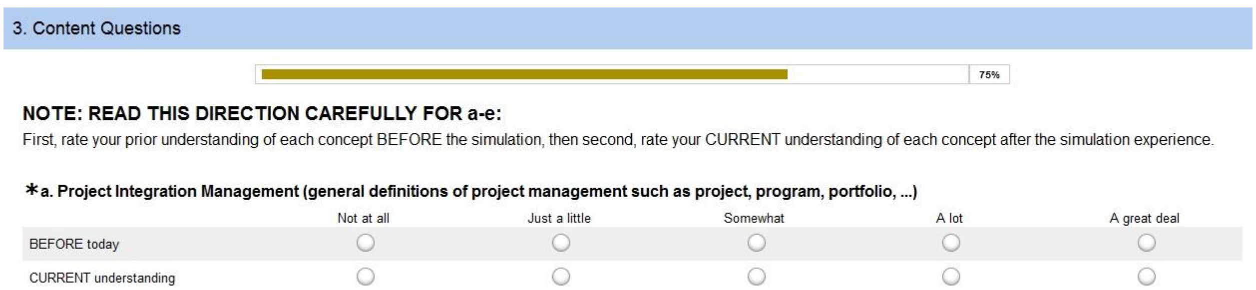


Figure 3-7: A sample of Post-Survey content question

The other part of this section asks about the factors impacting participants' performance in the simulation such as prior knowledge from experience, prior knowledge from classroom instruction, instructions within the simulation, and learning from mistakes.

The last section is Opinion Questions and contains questions about the participants' opinions in using project management simulation and its effect on learning, such as 1- how well simulation will help in learning real-world project time management concepts and strategies, 2- simulation instruction is a more effective learning tool than traditional lectures, 3- how much could be learned about project time management through simulation experience, and 4- simulation-based learning should be integrated throughout the construction program curriculum. The last section also asks about the level of participants' engagement on a 5-point scale and finally ends with open-ended questions about the weaknesses and strengths of PERFECT.

3.3 SUMMARY

This chapter reviewed the methodology used in the research project. The main sections of this chapter were research design and application and instrument design. In the research design, the interactive research design model (which justifies aspects of the research) was illustrated, and its elements (including goals, conceptual framework, research questions, methods, and validity) were explained. An explanation about the variables and population of this study followed the research design model. The elements of Pre-Quiz and Post Survey were explained, and it was shown how each item relates to the variables of this research study. In addition, ethical concerns related to this study were considered. The next chapter will provide the results obtained from different tools used in the project.

4 CHAPTER FOUR: RESULTS

VICE and PERFECT were tested between spring 2013 and summer 2014. The first analyses of VICE informed the experimental design of PERFECT. Therefore, PERFECT implementation benefited from the lessons learned through the planning, design, and analysis phases of VICE. Although VICE and PERFECT had similar structures and procedures, they focused on different areas of construction education; thus, they encompassed different elements. The results of each one are described in a separate section as follows.

4.1 VICE

VICE was the first application that was designed and tested during 2011-2014. The main focus of VICE was on those activities that are common to all single span construction projects. It provided basic contents of mobilization, excavation, sheet piles, pipe piles, cast in place, decking, and beams activities.

4.1.1 Procedure

VICE was tested with both high school and college students in three sessions between the summer of 2013 and the summer of 2014. The target group of VICE was students with no or little construction knowledge. High school students provided a baseline while the college students provided a comparison group. The high school group included 73 students, and the college group included 26 students.

A three-hour session was held for the VICE test, during which participants were asked to play the simulation in a local computer laboratory with 40 work stations.

College students participated in the VICE test as a class activity. Their participation did not affect their course grade. The procedure and main objectives of VICE were explained to participants at the beginning of the test. Results from the Pre-Quiz, main simulation, and Post-Survey were collected during each session. After signing the consent forms, participants began the Pre-Quiz, which took 40 minutes on average. Participants chose a username and password for the Pre-Quiz section, and kept them for the main simulation and Post-Survey. This allowed the integration of data across the test sections. The main simulation lasted approximately two hours on average. The performance data were stored in log files, which were retrieved by an administrator after all students had finished the simulation. Having finished the main simulation, participants were directed to an online survey in which they compared their before and after exposure situations.

4.1.2 Data Collection

VICE test data were collected through Pre-Quiz, main simulation, and Post-Survey data retrieving. Data gathered from Pre-Quiz and main simulation provided various comparisons to show the effectiveness of VICE. In addition, retrospective self-evaluation data showed participants' perceptions of knowledge gained as well as other descriptive statistical results. The performance data were converted to numeric values statistical analysis.

4.1.3 Data Analyses

To highlight differences between the subject groups, the results are shown for high school students and college students in the following sections.

4.1.3.1 Participation

Twenty-six students of construction-related programs in the Durham School of Architectural Engineering and Construction, as well as 73 high school students, participated in VICE tests.

4.1.3.2 Previous Virtual Learning Experience

Participants in both groups answered whether they had previous experience with virtual learning. The percentage of each group is shown in Figure 4-1.

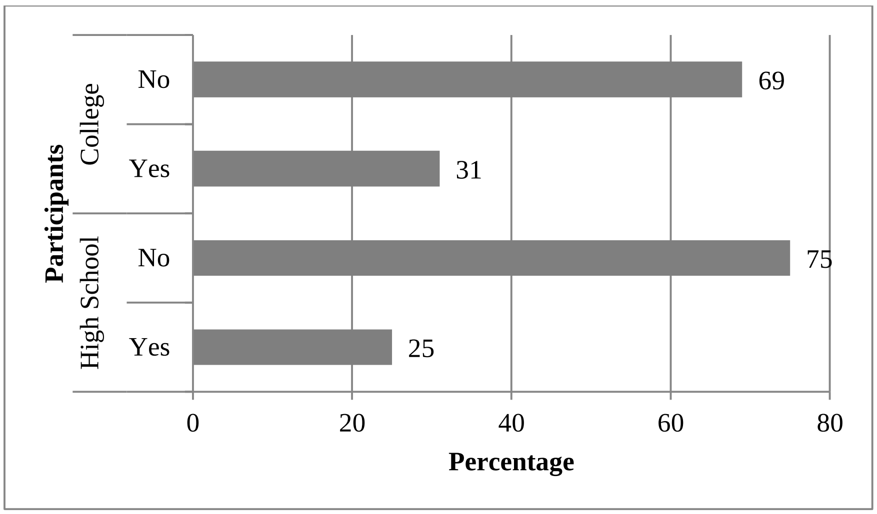


Figure 4-1: Previous virtual learning knowledge

4.1.3.3 Effect of VICE on Interest in STEM and Construction

VICE test participants were also asked to rate whether their interests in science, technology, engineering, mathematics (STEM) and construction increased after playing the simulation.

As shown in Table 4-1, the increases of interest in both subjects of construction and STEM areas are similar. On average, in the construction area, 43% of all participants stated that they "Totally Agree" or "Agree," while the numbers for each STEM area were 35%, 53%, 50%, and 35% respectively.

Table 4-1: Positive effect of VICE on participants' interest

Group	Level of Agreement	Construction	Science	Technology	Engineering	Mathematics
High School	Totally Disagree (%)	12	7	5	7	8
	Disagree (%)	33	15	12	15	18
	Neutral (%)	26	47	36	37	40
	Agree (%)	26	23	39	30	22
	Totally Agree (%)	3	8	8	11	12
	Total (%)	100	100	100	100	100
College	Totally Disagree (%)	0	4	0	0	4
	Disagree (%)	0	4	4	0	8
	Neutral (%)	19	46	27	27	49
	Agree (%)	58	42	61	61	35
	Totally Agree (%)	23	4	8	12	4
	Total (%)	100	100	100	100	100

4.1.3.4 Self-evaluation of Construction Knowledge Gained

Participants were asked to rate their perceived gains in construction knowledge through a self-evaluation survey in the following major subject areas of construction management:

a. Construction Process, Design and Management (managing equipment, personnel, and materials);
b. Materials and Equipment Methods (procuring equipment, concrete, aggregates, portland cement, compaction equipment, formwork, reinforcement, precast concrete);
c. Estimating (plan reading, specification, excavation, area and volume, concrete, earthwork);
d. Planning and Scheduling (work breakdown structure, scheduling sequencing, logic);
e. Cost Analysis and Control (financial management of costs for equipment, personnel, and materials);
f. Safety (OSHA, transportation safety, fall protection, concrete tools, and machines).

Participants rated their knowledge in each of these six areas for both before and after situations using a retrospective pre and post-survey. Possible responses were as follows: "Not at all," "Just a little," "Somewhat," "A lot," and "A great deal." Then, these responses were converted to values 1-5 respectively. Having completed a data set, appropriate statistical tests were utilized to show if there was a meaningful difference between the retrospective pre and post-test scores at a significance level of 0.05. As shown in Table 4-2, a Shapiro-Wilk's test (p>0.05) indicated the scores were not normally distributed for both pre and post groups in all six areas.

Table 4-2: Test of normality (college students)

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
aPost	.357	26	.000	.718	26	.000
aPre	.289	26	.000	.841	26	.001
bPost	.269	26	.000	.862	26	.003
bPre	.235	26	.001	.900	26	.015
cPost	.250	26	.000	.776	26	.000
cPre	.258	26	.000	.896	26	.013
dPost	.228	26	.001	.890	26	.009
dPre	.255	26	.000	.824	26	.000
ePost	.280	26	.000	.857	26	.002
ePre	.308	26	.000	.826	26	.001
fPost	.196	26	.011	.855	26	.002
fPre	.214	26	.003	.906	26	.021

Since the data distribution was found to be non-normal, the Wilcoxon test was used to determine if there was a meaningful difference between the pre and post-test knowledge gained scores at a significance level of 0.05. As shown in Table 4-3, the results indicated that that there was a significant difference between the mean of all pre and post-test scores of perceived construction content knowledge gained areas except for area f.

Table 4-3: Wilcoxon signed ranked test for college students

	aPre - aPost	bPre - bPost	cPre - cPost	dPre - dPost	ePre - ePost	fPre - fPost
Z	-3.130[b]	-2.399[b]	-3.260[b]	-2.738[b]	-2.540[b]	-.447[b]
Asymp. Sig. (2-tailed)	.002	.016	.001	.006	.011	.655

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

Since the data distribution of high school students was found to be normal (N>30), a t test was used to determine if there was a meaningful difference between the pre and post-test knowledge gained scores at a significance level of 0.05. Tables 4-4 and 4-5 show the results of the t test.

Table 4-4: High school students paired sample statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	aPost	2.6712	73	.85073	.09957
	aPre	1.4932	73	.64814	.07586
Pair 2	bPost	2.6849	73	.89562	.10482
	bPre	1.4932	73	.68967	.08072
Pair 3	cPost	2.7123	73	.87368	.10226
	cPre	1.7808	73	.86997	.10182
Pair 4	dPost	2.8356	73	1.01398	.11868
	dPre	1.9452	73	.89583	.10485
Pair 5	ePost	2.6986	73	.98157	.11488
	ePre	1.7671	73	.79093	.09257
Pair 6	fPost	2.3288	73	.95822	.11215
	fPre	1.7671	73	1.03442	.12107

Table 4-5: Paired sample t test for high school students

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	aPost - aPre	1.17808	1.04539	.12235	.93417	1.42199	9.628	72	.000
Pair 2	bPost - bPre	1.19178	1.07571	.12590	.94080	1.44276	9.466	72	.000
Pair 3	cPost - cPre	.93151	.93287	.10918	.71385	1.14916	8.532	72	.000
Pair 4	dPost - dPre	.89041	.79165	.09266	.70570	1.07512	9.610	72	.000
Pair 5	ePost - ePre	.93151	.94764	.11091	.71041	1.15261	8.399	72	.000
Pair 6	fPost - fPre	.56164	.84961	.09944	.36341	.75987	5.648	72	.000

The results indicate that there is a statistically significant difference between pre and post-test scores in all six areas of perceived construction knowledge gained.

4.1.3.5 Sources of Impact on Performance

Participants were asked to specify the impact of different factors on their performance while playing VICE. These factors included “Prior knowledge from experience,” “Prior knowledge from classroom,” “Instructions within the simulation,” “‘Ask a Consultant’ feature,” “Educational modules,” and “Learning from my mistakes.” Each factor was rated on a 5 level scale of “No help,” “A little help,” “Some help,” “Much help,” and “Excellent help.” Figures 4-2 and 4-3 show the percentage of each level among these factors in college and high school student groups, respectively.

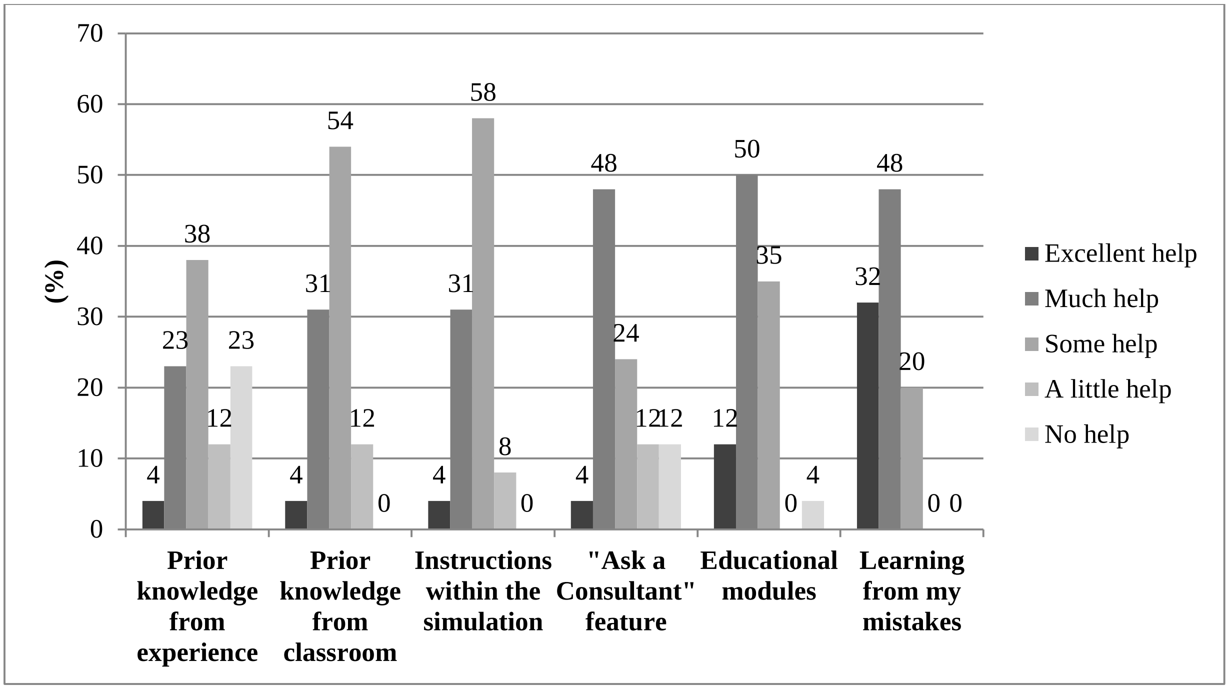


Figure 4-2: Source of impact on performance in college student group

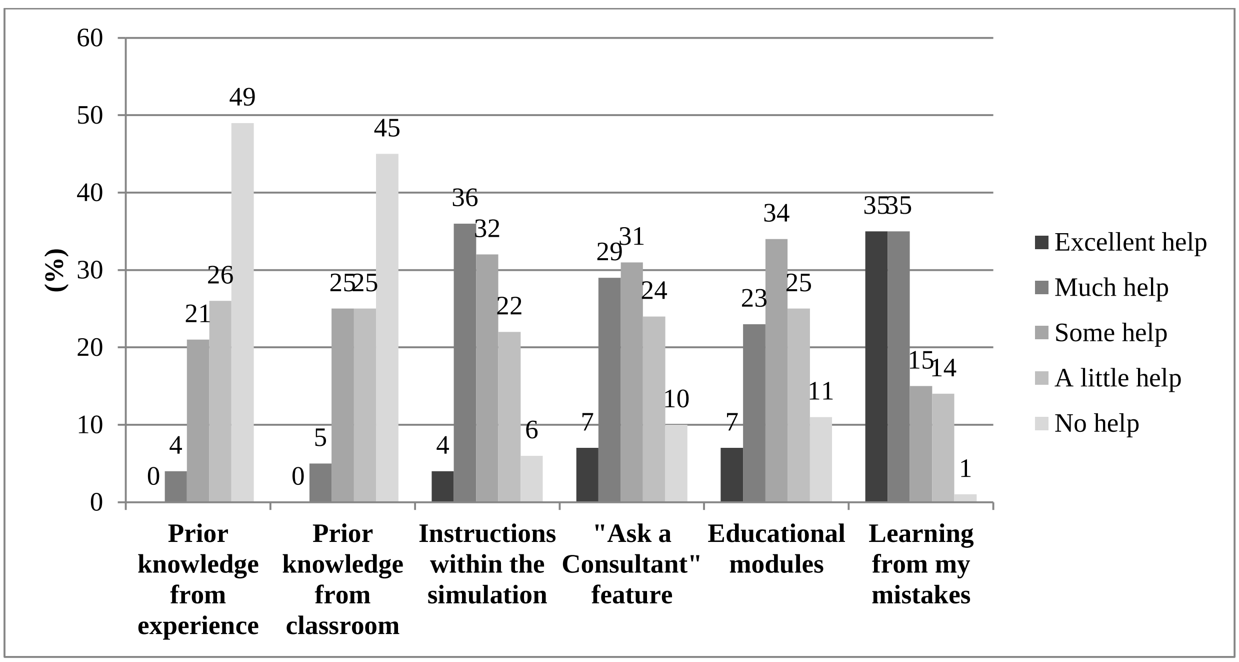


Figure 4-3: Source of impact on performance in high school student group

To show the relative weight of each item, numeric values 1 to 5 were respectively assigned to “No help,” “A little help,” “Some help,” “Much help,” and “Excellent help” options. Table 4-6 shows the relative average weight of each factor (out of 5) for both groups of college and high school students.

Table 4-6: Relative average weight of each impacting factor on performance

Group	Prior knowledge from experience	Prior knowledge from classroom	Instructions within the simulation	"Ask a Consultant" feature	Educational modules	Learning from my mistakes
High School	1.79	1.9	3.11	3	2.9	3.88
College	2.73	3.27	3.31	3.2	3.65	4.12

4.1.3.6 Using Simulation for Learning Real-World Construction Projects

VICE participants were also asked if they believed that simulations would help in learning real-world construction projects concepts. Table 4-7 shows that 40% of all participants agreed that simulations such as VICE can provide excellent help or much help in learning real-world construction project contents.

Table 4-7: Using simulation for learning real-world construction concepts (%)

	High School Students	College Students	All Participants
Excellent help (%)	1	0	1
Much help (%)	34	56	39
Some help (%)	36	36	36
A little help (%)	26	8	21
No help (%)	3	0	2
Sum (%)	100	100	100

4.1.3.7 Simulation and Project-based Learning vs. Traditional Tools

Participants were also asked to rate the following statements on a 5-point scale:

1: I find project-oriented delivery a more effective learning tool than traditional subject-based delivery.

2: I find simulation instruction to be a more effective learning tool than traditional lectures.

Tables 4-8 and 4-9 show the percentage of each level for both groups of college students and high school students, respectively. Although the percentage of "Totally Agree" and "Agree" was high for both groups, college students indicated a higher level of agreement for both questions.

Table 4-8: Project-based learning and simulation vs. traditional lectures – college students (%)

	1-Project-oriented delivery is a more effective learning tool than traditional subject-based delivery.	2- Simulations are more effective learning tools than traditional lectures.
Totally Disagree (%)	0	0
Disagree (%)	0	12
Neutral (%)	35	35
Agree (%)	57	49
Totally Agree (%)	8	4
Sum (%)	100	100

Table 4-9: Project-based learning and simulation vs. traditional lectures – high school students (%)

	1-Project-oriented delivery is a more effective learning tool than traditional subject-based delivery.	2- Simulations are more effective learning tools than traditional lectures.
Totally Disagree (%)	4	10
Disagree (%)	8	7
Neutral (%)	36	43
Agree (%)	41	36
Totally Agree (%)	11	4
Sum (%)	100	100

4.1.3.8 Level of Engagement

Level of engagement was measured using a question that simply asked the participants to rate their level of engagement during the simulation on a 4-point scale. Possible ranks included "Not very engaged," "Mildly engaged," "Very engaged," and "Thoroughly engaged," and values 1 to 4 were assigned to them respectively. Figure 4-4 provides the percentage of each level of engagement.

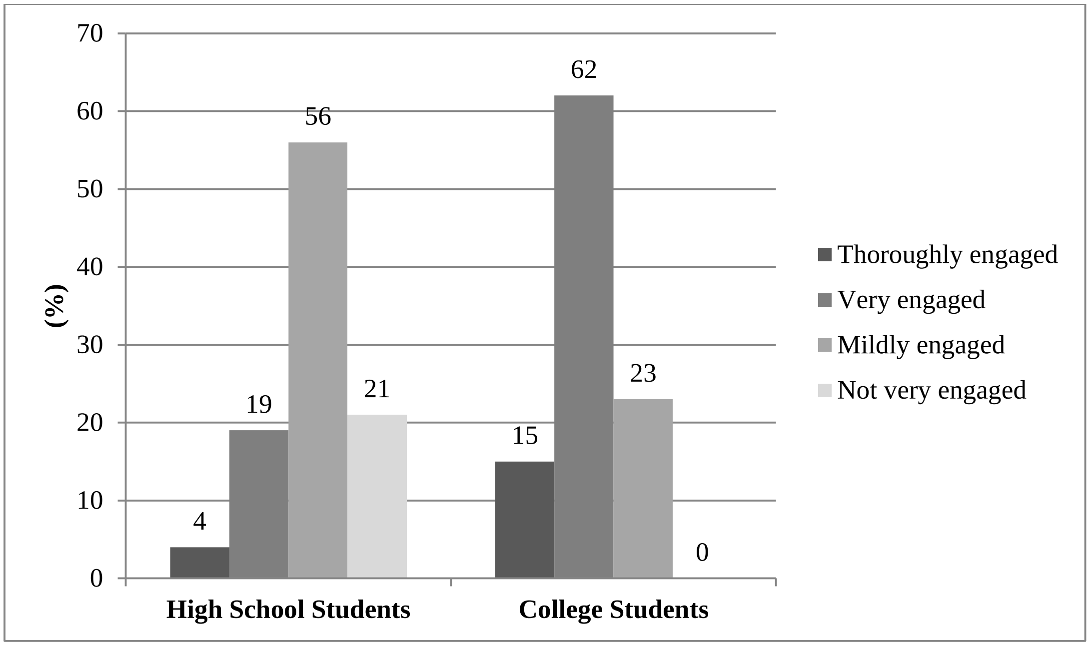


Figure 4-4: Level of engagement in high school and college students

The mean and standard deviation in the high school student group were 2.07 and 0.75 respectively. Corresponding numbers in the college student group were 2.92 and 0.62.

4.1.3.9 Integration of Project-based Learning and Simulation with Construction Curricula

Participants were also asked if they thought that project-based learning methods and simulation should be integrated with construction curricula. For these questions, levels of agreement were "Totally Disagree," "Disagree," "Neutral," "Agree," and "Totally Agree." Tables 4-10 and 4-11 show the percentage of each level for college students and high school students, respectively.

Table 4-10: Integration of project-based learning and simulation with construction curriculum – college students (%)

	1- I believe *project-based learning* should be integrated throughout the construction program curriculum.	2-I believe *simulation-based learning* should be integrated throughout the construction program curriculum.
Totally Disagree (%)	0	0
Disagree (%)	0	0
Neutral (%)	19	19
Agree (%)	58	73
Totally Agree (%)	23	8
Sum (%)	100	100

Table 4-11: Integration of project-based learning and simulation with construction curriculum – high school students

	1- I believe *project-based learning* should be integrated throughout the construction program curriculum.	2-I believe *simulation-based learning* should be integrated throughout the construction program curriculum.
Totally Disagree (%)	0	5
Disagree (%)	3	7
Neutral (%)	26	45
Agree (%)	50	32
Totally Agree (%)	21	11
Sum (%)	100	100

4.1.3.10 Actual Performance of Participants

To investigate the effectiveness of VICE, in addition to the retrospective self-evaluation survey, the data of participants' performance through Pre-Quiz and main simulation were collected and analyzed. Numeric values of 4, 3, 2, and 1 were assigned to these situations, respectively, in both Pre-Quiz and main simulation:

a: participant answered the question in the first attempt

b: participant answered the question in the second attempt

c: participant answered the question in the third attempt

d: participant could not answer the question correctly within three allowed attempts.

Thirteen questions were selected from Pre-Quiz and the main simulation and compared to each other for both high school and college student groups. Since 27 students participated in the college student group, a test of normality was performed, as shown in Table 4-12. As the results indicate, the data are not normally distributed, so a Wilcoxon test was used to show any difference between the means of Pre-Quiz and the main simulation pairs. As shown in Table 4-13, the results indicate that there was a significant difference between the mean scores of all Pre-Quiz and main simulation scores questions, except for questions 9 and 10.

The same comparison was also performed for high school students. Since 73 students participated in the test and, therefore, the data were normally distributed, a paired sample t test was used to determine if there was a meaningful difference between the Pre-Quiz and the main simulation groups. The data statistics and t test results are shown in Tables 4-14 and 4-15 respectively. The results indicate that there is a statistically significant difference between the mean scores of all Pre-Quiz and main simulation scores questions, except for questions 9 and 10.

Table 4-12: Test of normality for college student group

Tests of Normality[a,c,d,e]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Q1Post	.281	26	.000	.734	26	.000
Q2Pre	.272	26	.000	.806	26	.000
Q2Post	.327	26	.000	.664	26	.000
Q3Pre	.310	26	.000	.775	26	.000
Q3Post	.448	26	.000	.539	26	.000
Q4Pre	.294	26	.000	.776	26	.000
Q4Post	.319	26	.000	.745	26	.000
Q5Pre	.406	26	.000	.629	26	.000
Q5Post	.504	26	.000	.349	26	.000
Q6Pre	.539	26	.000	.198	26	.000
Q6Post	.275	26	.000	.757	26	.000
Q7Pre	.456	26	.000	.550	26	.000
Q7Post	.322	26	.000	.742	26	.000
Q8Pre	.539	26	.000	.198	26	.000
Q8Post	.271	26	.000	.748	26	.000
Q9Post	.539	26	.000	.198	26	.000
Q11Pre	.445	26	.000	.574	26	.000
Q11Post	.248	26	.000	.776	26	.000
Q12Pre	.391	26	.000	.640	26	.000
Q12Post	.310	26	.000	.716	26	.000
Q13Pre	.383	26	.000	.701	26	.000
Q13Post	.268	26	.000	.787	26	.000

a. Q1Pre is constant. It has been omitted.

b. Lilliefors Significance Correction

c. Q9Pre is constant. It has been omitted.

d. Q10Pre is constant. It has been omitted.

e. Q10Post is constant. It has been omitted.

Table 4-13: Wilcoxon test for college students group

Test Statistics[a]

	Q1Pre - Q1Post	Q2Pre - Q2Post	Q3Pre - Q3Post	Q4Pre - Q4Post	Q5Pre - Q5Post	Q6Pre - Q6Post	Q7Pre - Q7Post	Q8Pre - Q8Post	Q9Pre - Q9Post	Q10Pre - Q10Post	Q11Pre - Q11Post	Q12Pre - Q12Post	Q13Pre - Q13Post
Z	-4.320[b]	-1.987[b]	-3.779[b]	-2.186[b]	-2.537[b]	-3.477[b]	-2.469[b]	-3.934[b]	-1.000[b]	.000[c]	-2.574[b]	-2.235[b]	-2.326[b]
Asymp. Sig. (2-tailed)	.000	.047	.000	.029	.011	.001	.014	.000	.317	1.000	.010	.025	.020

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. The sum of negative ranks equals the sum of positive ranks.

Table 4-14: High school student group's paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Q1Post	2.6301	73	1.33860	.15667
	Q1Pre	1.0000	73	.00000	.00000
Pair 2	Q2Post	3.2329	73	.93572	.10952
	Q2Pre	2.3699	73	1.25285	.14664
Pair 3	Q3Post	2.8904	73	1.19677	.14007
	Q3Pre	1.9041	73	1.16862	.13678
Pair 4	Q4Post	3.1233	73	1.21272	.14194
	Q4Pre	2.0548	73	1.20058	.14052
Pair 5	Q5Post	3.3151	73	1.02573	.12005
	Q5Pre	1.9452	73	1.32172	.15470
Pair 6	Q6Post	1.5890	73	1.07801	.12617
	Q6Pre	1.0685	73	.41928	.04907
Pair 7	Q7Post	1.9315	73	1.31581	.15400
	Q7Pre	1.0000	73	.00000	.00000
Pair 8	Q8Post	1.1781	73	.67376	.07886
	Q8Pre	1.0000	73	.00000	.00000
Pair 9	Q9Post	1.0000[a]	73	.00000	.00000
	Q9Pre	1.0000[a]	73	.00000	.00000
Pair 10	Q10Post	1.0000[a]	73	.00000	.00000
	Q10Pre	1.0000[a]	73	.00000	.00000
Pair 11	Q11Post	1.9589	73	.48415	.05667
	Q11Pre	1.0000	73	.00000	.00000
Pair 12	Q12Post	1.6712	73	1.01454	.11874
	Q12Pre	1.0137	73	.11704	.01370
Pair 13	Q13Post	1.3562	73	.48218	.05643
	Q13Pre	1.0548	73	.32874	.03848

a. The correlation and t cannot be computed because the standard error of the difference is 0.

Table 4-15: High school student group's paired samples t test results

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Q1Post - Q1Pre	1.63014	1.33860	.15667	1.31782	1.94246	10.405	72	.000
Pair 2	Q2Post - Q2Pre	.86301	1.40747	.16473	.53463	1.19140	5.239	72	.000
Pair 3	Q3Post - Q3Pre	.98630	1.73600	.20318	.58126	1.39134	4.854	72	.000
Pair 4	Q4Post - Q4Pre	1.06849	1.41744	.16590	.73778	1.39921	6.441	72	.000
Pair 5	Q5Post - Q5Pre	1.36986	1.67089	.19556	.98002	1.75971	7.005	72	.000
Pair 6	Q6Post - Q6Pre	.52055	1.19152	.13946	.24255	.79855	3.733	72	.000
Pair 7	Q7Post - Q7Pre	.93151	1.31581	.15400	.62451	1.23851	6.049	72	.000
Pair 8	Q8Post - Q8Pre	.17808	.67376	.07886	.02088	.33528	2.258	72	.027
Pair 11	Q11Post - Q11Pre	.95890	.48415	.05667	.84594	1.07186	16.922	72	.000
Pair 12	Q12Post - Q12Pre	.65753	.98910	.11576	.42676	.88831	5.680	72	.000
Pair 13	Q13Post - Q13Pre	.30137	.51868	.06071	.18035	.42239	4.964	72	.000

4.2 PERFECT

PERFECT was the second simulation application that was tested. PERFECT provided concepts of project time management based on the PMBOK standard. It covered basic project time management subjects such as general definitions of project management terms, activity definition and sequencing, cost and duration estimation, and the precedence diagram method (Rokooei, Goedert, & Fickle, 2015).

4.2.1 Procedure

PERFECT was tested with two groups of construction students in fall 2014. The first group included 30 students who had related knowledge about the project time management subjects due to taking the CONE 4850 & CNST 4850 course titled "Construction Planning, Scheduling, and Controls." The second group of 30 students had not taken that course when they played PERFECT.

A three-hour practicum session was conducted for the application during which participants were asked to play the simulation in a local computer laboratory with 40 work stations. Students participated in the PERFECT test as a class activity; however, participation in the project test was voluntary. The test was conducted in two sessions, a Pre-Quiz session and the main simulation. At the beginning of the test session, participants were briefed on the purposes of the research project and the way the application worked. A code was assigned to each participant to use as an integrator of different application elements including Pre-Quiz, main simulation, and Post-Survey. Participants were assured of the confidentiality of their information and results, and that their performance on the simulation would not affect their grade in the course.

After turning in the signed consent forms, participants began the Pre-Quiz, which took 45 minutes on average. The main simulation took two hours on average, and the results were coded and saved. After completing the simulation, participants were directed to the online survey, in which they compared the perception of knowledge gained for before and after exposure.

4.2.2 Data Collection

Data collection was performed from Pre-Quiz and main simulation performance as well as for the online Post-Survey. The former group of data included the actual performance of participants' data that showed the effectiveness of simulation, and the latter one consisted of self-evaluation questions that measured the level of learning, engagement, and participants' perception of the simulation. Demographic information – such as age, gender, academic standing, work experience, and previous experience with simulation and educational games – as collected to improve the completeness of the analysis and provide a better understanding of probable correlations. The level of project management knowledge of participants through previous courses or any external experience was measured through open-ended questions. These questions categorized participants into two groups of "no project time management knowledge" and "with project time management knowledge." Most questions used to compare the before and after situations, as well as to rate the effects of simulation on related subjects, were 5-level questions. In addition, to reflect the specific opinions of participants, such as the weaknesses and strengths of simulation, open-ended questions were used in the online Post-Survey. Closed-ended questions and Likert-scale items were analyzed using appropriate statistical tools, and their results are shown in the following sections.

4.2.3 Analyses Results

The results of the PERFECT tests are provided based on two parts of actual performance and self-evaluation for two groups of participants.

4.2.3.1 Participation

Sixty students of construction-related programs in the Durham School of Architectural Engineering and Construction participated in the PERFECT test in fall 2014. In order to increase ease of use and clarify the results, two groups of participants with project time management knowledge and without project time management knowledge were named Group A and Group B, respectively.

The average of participants' ages in Group A and B were 24.2 and 21.9 years respectively. Also both groups consisted of 93% male and 7% female participants.

4.2.3.2 Previous Virtual Learning Experience

Participants in both groups indicated if they had previous experience with virtual learning. The percentage of each group is shown in Figure 4-5.

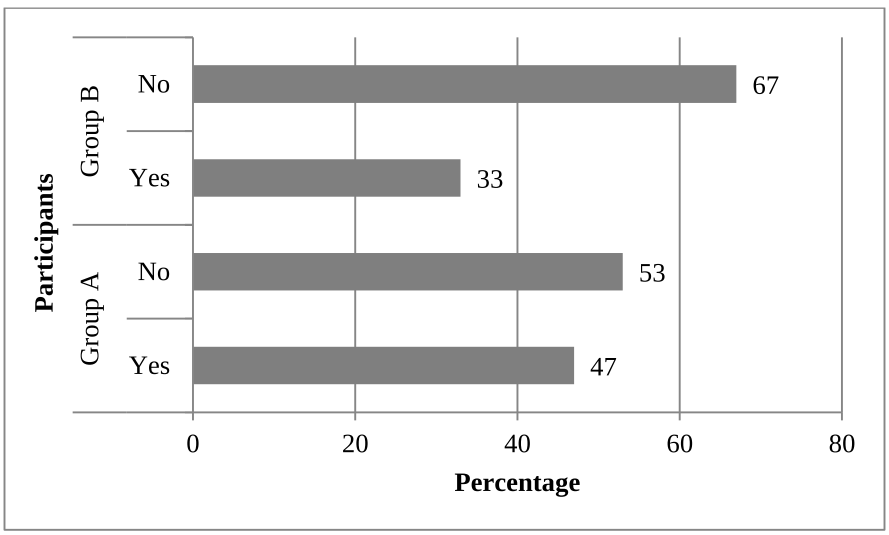


Figure 4-5: Previous virtual learning knowledge

4.2.3.3 Effect of PERFECT on Interest in Construction and Project Management

Participants were also asked if their interests in construction and project management had increased after playing PERFECT. As shown in Table 4-16, the levels of interest in both subjects of construction and project management were similar. On average, in the construction area, 3% of all participants were "Totally Disagree" or "Disagree," while 47% stated that they were "Totally Agree" or "Agree" that their interests had increased as a result of playing PERFECT. Those two numbers in the project management area were 5% and 40%, respectively.

Table 4-16: Effect of simulation on participants' interest

Group	Level of Agreement	My interest in Construction has improved as a result of this exercise.	My interest in Project Management has improved as a result of this exercise.
A	Totally Disagree (%)	3	3
	Disagree (%)	0	0
	Neutral (%)	60	63
	Agree (%)	37	33
	Totally Agree (%)	0	0
	Total (%)	100	100
B	Totally Disagree (%)	0	0
	Disagree (%)	3	7
	Neutral (%)	40	37
	Agree (%)	47	47
	Totally Agree (%)	10	10
	Total (%)	100	100

4.2.3.4 Self-evaluation of Project Time Management Knowledge Gained

Participants in both groups were also asked to self-evaluate their project time management knowledge using retrospective pre and post assessment after playing PERFECT. Based on the contents of simulation and the main process of project time management, the retrospective pre and post questions were organized in four areas of a, b, c, and d as follows:

a. Project Integration Management (general definitions of project management such as project, program, portfolio, etc.);

b. Define Activity Process (activity definition, WBS, milestone, etc.) and Sequence Activity Process (lag, lead, precedence diagramming method, dependencies: SS, FF, SF, FS, etc.);

c. Estimate Activity Resources Process (bottom-up estimation, top-down estimation, etc.) and Estimate Activity Duration Process (three-point estimation, parametric estimation, expert judgment, analogous estimation, etc.);

d. Develop Schedule (drawing CPM, fast tracking, crashing…) and Control Schedule (control schedule inputs, tools and outputs, etc.).

Possible ratings of “Not at all,” “Just a little,” “Somewhat,” “A lot,” and “A great deal” were quantified with numeric values of 1, 2, 3, 4, and 5, respectively and then a paired sample t test was utilized to determine the mean difference between the retrospective pre and post-test scores in Group A at a significance level of 0.05. The mean and standard deviation of each pair are shown in Table 4-17.

Table 4-17: Group A paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	aPost	3.37	30	.556	.102
	aPre	3.00	30	.788	.144
Pair 2	bPost	3.83	30	.747	.136
	bPre	3.80	30	.714	.130
Pair 3	cPost	3.40	30	.724	.132
	cPre	3.23	30	.817	.149
Pair 4	dPost	3.77	30	.728	.133
	dPre	3.57	30	.858	.157

In addition, as shown in Table 4-18, there was a statistically significant difference between pre and post-test scores in Group A at a significance level of 0.05 in areas a and d, but there was no difference at a significance level of 0.05 in areas b and c.

Table 4-18: Group A self-evaluation paired samples t test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	aPost - aPre	.367	.615	.112	.137	.596	3.266	29	.003
Pair 2	bPost - bPre	.033	.490	.089	-.150	.216	.372	29	.712
Pair 3	cPost - cPre	.167	.461	.084	-.006	.339	1.980	29	.057
Pair 4	dPost - dPre	.200	.484	.088	.019	.381	2.262	29	.031

A similar procedure was done for four areas in Group B. Table 4-19 shows the mean and standard deviation of each pair in Group B. A paired sample t test was utilized to determine the mean difference between the retrospective pre and post-test scores in Group B at a significance level of 0.05. As shown in Table 4-20, there was a statistically significant difference between pre and post-test scores in Group B at a significance level of 0.05 in all areas.

Table 4-19: Group B paired samples statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	aPost	3.50	30	.731	.133
	aPre	2.37	30	.928	.169
Pair 2	bPost	3.40	30	.894	.163
	bPre	2.50	30	1.009	.184
Pair 3	cPost	3.07	30	.828	.151
	cPre	2.30	30	.750	.137
Pair 4	dPost	3.27	30	.785	.143
	dPre	2.37	30	.850	.155

Table 4-20: Group B self-evaluation paired samples t test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	aPost - aPre	1.133	.900	.164	.797	1.469	6.901	29	.000
Pair 2	bPost - bPre	.900	.885	.162	.570	1.230	5.572	29	.000
Pair 3	cPost - cPre	.767	.858	.157	.446	1.087	4.892	29	.000
Pair 4	dPost - dPre	.900	.712	.130	.634	1.166	6.924	29	.000

4.2.3.5 Sources of Impact on Performance

Participants were asked to determine the impact of different factors on their performance. These factors included “Prior knowledge from experience,” “Prior knowledge from classroom instruction,” “Instructions within the simulation,” and

"Learning from my mistakes." Each factor was rated on a 5-level scale of "No help," "A little help," "Some help," "Much help," and "Excellent help." Figures 4-5 and 4-6 show the percentage of each level among these factors in Group A and Group B, respectively.

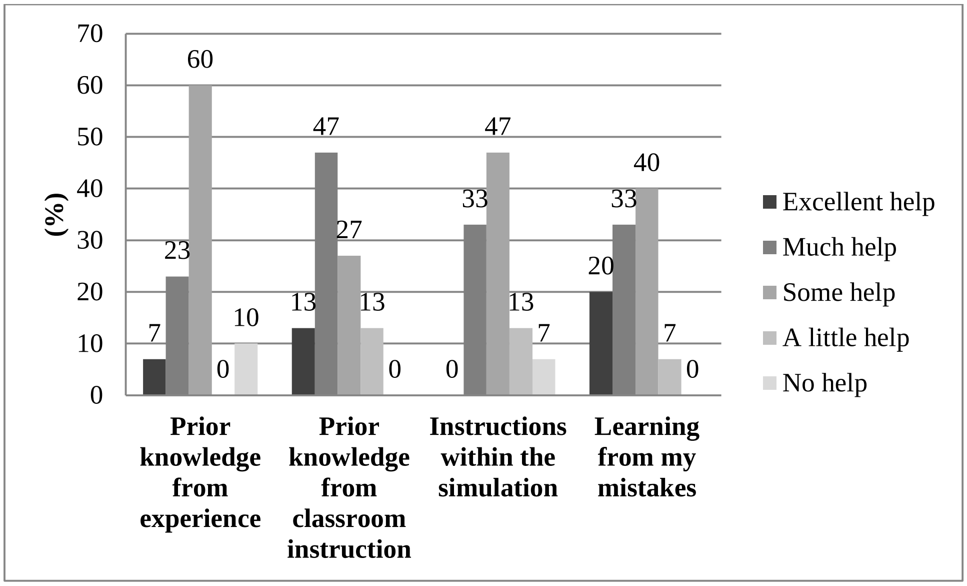


Figure 4-6: Sources of impact on performance in Group A

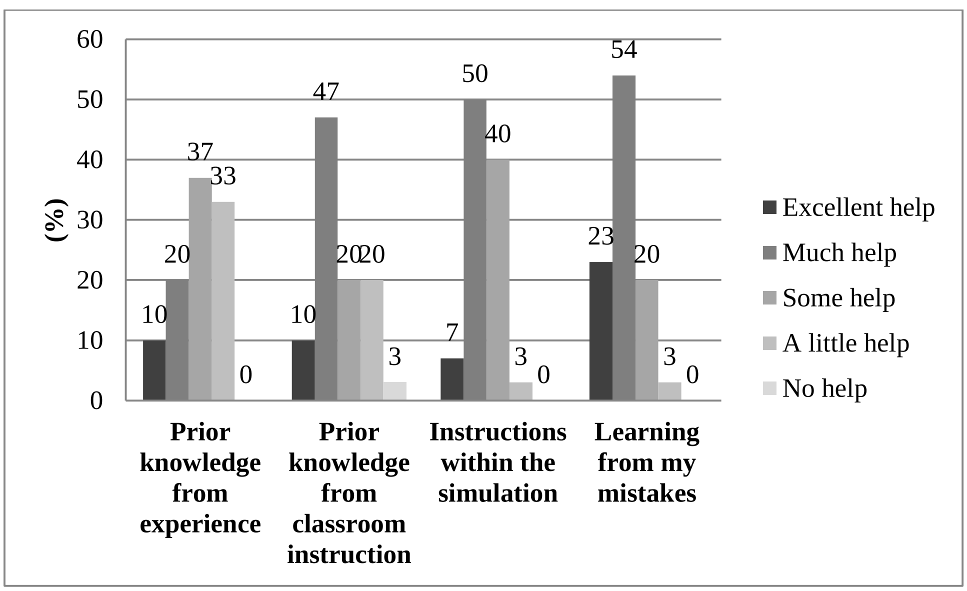


Figure 4-7: Sources of impact on performance in Group B

To determine the relative weight of each factor, values 1 to 5 were assigned, respectively, to “No help,” “A little help,” “Some help,” “Much help,” and “Excellent help” options. Table 4-21 shows the relative average weight of each factor (out of 5) for Groups A and B.

Table 4-21: Relative average weight of each impacting factor on performance

Group	Prior knowledge from experience	Prior knowledge from classroom instruction	Instructions within the simulation	Learning from my mistakes
A	3.17	3.6	3.07	3.67
B	3.07	3.4	3.6	3.97

4.2.3.6 PERFECT Help in Learning Real-World Project Time Management

Participants were also asked to answer how well they thought PERFECT would help in learning real-world project time management concepts and strategies on a 5-level scale. The percentage of each level for both Group A and Group B is shown Table 4-22.

Table 4-22: PERFECT help in learning real-world project time management

	Group A	Group B
No help (%)	13	0
A little help (%)	3	13
Some help (%)	54	40
Much help (%)	30	40
Excellent help (%)	0	7

4.2.3.7 Comparison of Simulations and Traditional Lectures

In another question, participants rated “I find simulation instruction to be a more effective learning tool than traditional lectures” on a 5-level scale. The percentage of each level for both Group A and Group B is shown in Table 4-23.

Table 4-23: Simulations are more effective than traditional lectures

	Group A	Group B
Totally Disagree (%)	13	7
Disagree (%)	17	21
Neutral (%)	40	38
Agree (%)	30	24
Totally Agree (%)	0	10

4.2.3.8 Level of Engagement

Level of engagement was measured using a question that simply asked the participants to rate their level of engagement during the simulation on a 5-point level scale. Figure 4-7 provides the scale for level of engagement. Responses were given a numerical score from 1 to 5. The mean and standard deviation in Group A were 3.07 and 1 respectively. Corresponding numbers in Group B were 3.23 and 0.80.

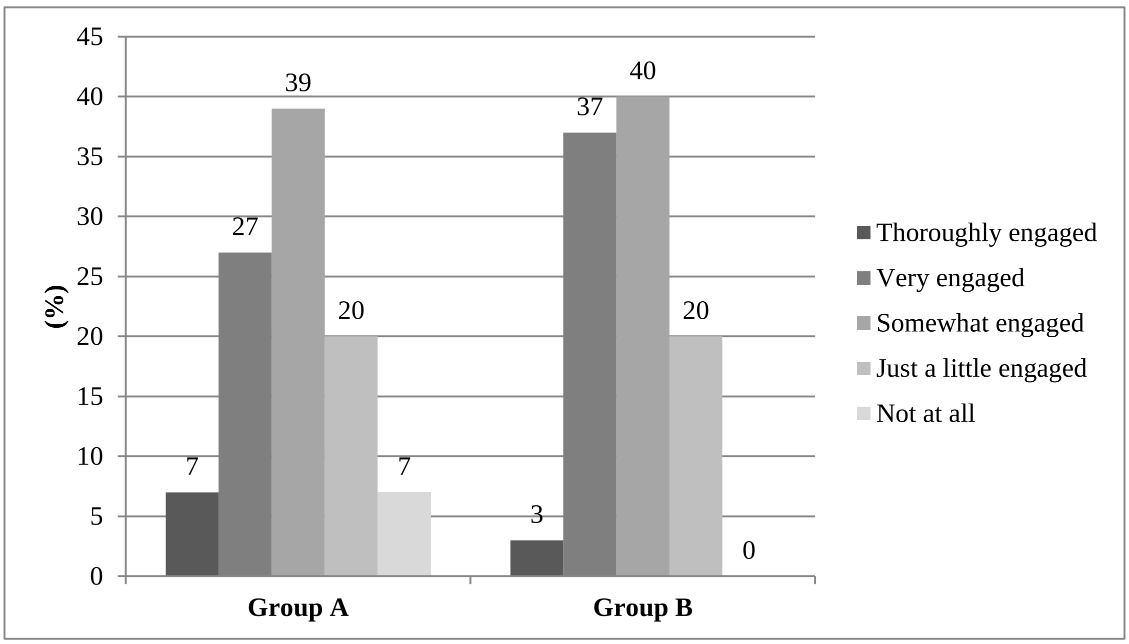


Figure 4-8: Level of engagement

4.2.3.9 Learning Project Time Management through Simulations

Participants were asked how much they thought could be learned about project time management through simulation experience such as what they had experienced with PERFECT. They rated their responses on a 5-point level scale. The percentage of each level is shown in Table 4-24 for both Groups A and B.

Table 4-24: Learning project time management through simulations

	Group A	Group B
None (%)	3	0
Just a little (%)	0	0
Some (%)	37	30
A lot (%)	50	63
Most everything (%)	10	7

4.2.3.10 Integration of Simulation-based Learning with Construction Curricula

Participants were also asked if they believed simulation-based learning should be integrated throughout the construction program curricula on a 5-point level scale. The percentage of each level is shown in Table 4-25 for both Groups A and B.

Table 4-25: Integration of simulation-based learning throughout construction curricula

	Group A	Group B
Totally Disagree (%)	10	3
Disagree (%)	17	17
Neutral (%)	47	30
Agree (%)	23	43
Totally Agree (%)	3	7

4.2.3.11 Actual Performance of Participants

In addition to measuring the effectiveness of PERFECT by using a retrospective self-evaluation survey, the actual performance of participants was measured through a pre and post-situations comparison. Thirty-seven project time management questions were determined to cover the material provided in PERFECT. These questions encompassed subjects that are presented in the project time management chapter of the PMBOK standard. Based on the titles of project time management, four main categories were specified, and each of these questions was assigned to one area. These areas included a. Project Integration Management, b. Define Activity Process, c. Estimate Activity Resources, and d. Develop Schedule. These correspond to the four areas presented in the Post-Survey. Areas a, b, c, and d consisted of 10, 10, 8, and 9 questions, respectively. As discussed in Methodology, based on the number of attempts to reach the correct answer, a value from 1 to 4 was assigned to each answer in both Pre-Quiz and main simulation. Then, the values of each area in Pre-Quiz were classified and compared with corresponding values in main simulation. Tables 4-26 and 4-27 show the means and standard deviations of each area for Groups A and B respectively. A paired sample t test was utilized to determine the mean difference between the retrospective pre and post-test scores in Groups A and B at a significance level of 0.05 as shown in Table 4-28 and 4-29, respectively.

Table 4-26: Group A paired sample statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	aPost	3.54	300	.819	.047
	aPre	2.70	300	1.285	.074
Pair 2	bPost	3.52	300	.832	.048
	bPre	2.97	300	1.224	.071
Pair 3	cPost	3.37	240	.933	.060
	cPre	2.53	240	1.223	.079
Pair 4	dPost	3.67	270	.662	.040
	dPre	3.20	270	1.138	.069

Table 4-27: Group B paired sample statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	aPost	3.44	300	.932	.054
	aPre	2.60	300	1.311	.076
Pair 2	bPost	3.34	300	.980	.057
	bPre	2.53	300	1.281	.074
Pair 3	cPost	3.14	240	1.052	.068
	cPre	2.44	240	1.266	.082
Pair 4	dPost	3.41	270	.931	.057
	dPre	2.32	270	1.242	.076

Table 4-28: Group A actual performance paired samples t test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	aPost - aPre	.840	1.273	.073	.695	.985	11.432	299	.000
Pair 2	bPost - bPre	.553	1.222	.071	.415	.692	7.846	299	.000
Pair 3	cPost - cPre	.837	1.385	.089	.661	1.014	9.366	239	.000
Pair 4	dPost - dPre	.470	1.093	.067	.339	.601	7.072	269	.000

Table 4-29: Group B actual performance paired samples t test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	aPost - aPre	.837	1.323	.076	.686	.987	10.957	299	.000
Pair 2	bPost - bPre	.813	1.467	.085	.647	.980	9.602	299	.000
Pair 3	cPost - cPre	.700	1.548	.100	.503	.897	7.007	239	.000
Pair 4	dPost - dPre	1.085	1.413	.086	.916	1.254	12.620	269	.000

As shown in the tables above, there was a statistically significant difference between pre and post-test scores in Groups A and B at a significance level of 0.05 in all categories. In addition, a comparison between pre and post scores of each of the 37 questions was conducted, which is presented in Appendix D.

4.3 SUMMARY

This chapter briefly reviewed the results derived from VICE and PERFECT tests. The procedure of the test was separately described for both applications. In the next section, data collection from Pre-Quiz, main simulation, and Post-Survey was explained. General information about each test group was provided, and it was shown how the data retrieved from Pre-Quiz and main simulation were compared with the Post-Survey data. The next section provided the analyses results of both applications. Previous virtual learning experience, effect of simulation applications on interest in STEM and construction project management, source of impact on performance, using simulation for learning real-world projects, integration of project-based learning and simulation with construction curriculum, comparison of traditional learning method with project-based learning method, level of engagement, actual performance of participants, and the comparison between actual performance and self-evaluation results, as the subject of each part, were illustrated in the data analyses section. The next chapter provides interpretation of findings, limitations, recommendations, and directions for future research.

5 DISCUSSION

This chapter discusses the results of the research project exploring the value and effectiveness of simulations in construction project management education. This chapter begins with an interpretation of findings from both VICE and PERFECT simulations. This is followed by a discussion on the limitations of the study. Then, recommendations and directions for future research are provided. A brief summary of this research ends this chapter.

5.1 INTERPRETATION OF FINDINGS

Findings of the research project (including the self-evaluated perceptions of students, level of engagement, increase of interests, actual performance of participants, etc. for VICE and PERFECT) are explained respectively in the following sections.

5.1.1 VICE

The results of the VICE application demonstrated its merit in providing an interactive project-based learning experience in construction education. In support of the project objectives, participants reported an increase in perceived knowledge about construction activities including design process, materials and equipment methods, estimating, scheduling, and cost analysis. To better illustrate the implications of the findings, results were interpreted and presented to correspond with the research questions:

- *What is the effect of the simulation on participants' perceptions in project management?*

The majority of both participant groups of VICE did not have previous experience with virtual learning. Their level of interest in science, technology, engineering, and mathematics (STEM) and construction increased after playing the simulation. Both groups demonstrated similar patterns in STEM areas. Due to the features of the VICE application, technology and engineering areas had higher percentages in “Totally Agree” and “Agree” levels. The main difference between high school and college student groups was the percentage of increase in their interests in the construction area after playing VICE. While only 29% of high school students chose “Totally Agree” or “Agree” that playing VICE increased their interests in the construction area, college students weighted these two levels as 81%. Moreover, no one in the college student group disagreed with the above statement. It can be concluded that previous familiarity with the construction contents had a noticeable impact on the perceptions of simulation participants.

Another similarity of both VICE groups was participants’ perception of potential factors that affected the performance. “Excellent help” had the highest percentage in the “learning from mistakes” factor in both groups. This indicates that the repeatability feature of the simulation, which enables participants to form mental models and scaffold learning, had a significant role in the learning process. This repeatability potential was accessible in all resource selection and educational modules throughout the VICE application.

Although both VICE participant groups demonstrated simulations could be “Excellent help” or “Much help” in learning real-world construction projects, the college students showed a higher agreement level. When both groups rated whether simulations and project-based learning delivery were more effective ways than traditional lecture-based methods, they showed a similar level of agreement. However, when participants rated if they thought that project-based learning methods and simulations should be integrated with construction curricula, college students demonstrated a higher level of agreement.

- *What is the effect of simulation on the level of participants' engagement?*

Level of engagement was measured numerically for both VICE participant groups. Although level of engagement is a behavioral aspect of simulations, and, thus, it is hard to measure and compare, a direct question about level of engagement can provide a rough representation of qualitative aspects through quantitative levels. Both high school students and college students demonstrated an above-average level of engagement. However, college students stated a considerably higher level of engagement.

- *What is the relationship between the actual performance of participants and their perceptions about content knowledge gained?*

The effectiveness of the VICE application was examined using two methods: self-evaluation and actual performance. Data retrieved from Pre-Quiz and the main simulation were compared to demonstrate any meaningful differences. As illustrated in Chapter 4, the Wilcoxon test results indicated there was a meaningful difference between the pre and post-test knowledge gained scores of the college student group at a significance level of 0.05. A similar significant difference was found for high school students; a t test showed that the mean scores of pre and post-test knowledge gained differed at a significance level of 0.05. Although the questions provided in Pre-Quiz and the main simulation are not exhaustive, and do not cover the whole subjects of construction, the results of both experiment groups showed there was a difference between pre and post situations. Thus, VICE can be considered as an effective tool in construction education. Moreover, the retrospective Post-Survey results, as discussed in Chapter 4, indicated similar outcomes for both groups of high school and college students. Therefore, it can be concluded that the results of self-evaluation measurement coincided with the results of actual performance assessment.

5.1.2 PERFECT

PERFECT was a complementary application for the research that focused on project time management in construction. The research objectives and research questions in the PERFECT application remained unchanged from the VICE project. As illustrated in the methodology section, a similar approach was used in structuring, data capturing, and analyzing the PERFECT application. The results were shown in Chapter 4. In order to demonstrate the implications of the findings, and support the outcomes of VICE, results were interpreted according to research questions as follows:

- *What is the effect of the simulation on participants' perceptions of project management?*

Although in Group A, a higher portion of participants had previous experience in virtual learning, the majority of both participant groups of PERFECT did not have previous experience with virtual learning. Thirty-seven percent of participants in Group A selected “Agree” or “Totally Agree” to indicate the increase of their interest in construction after playing PERFECT. This is in contrast with 3% who chose “Disagree” or "Totally Disagree." In responding to another question about the increase of interest in project management, the corresponding percentages were 33% and 3%, respectively. This shows a positive effect of PERFECT on participants' interests in construction and project management. This positive attitude was shown more vividly in Group B, where 57% of participants stated their positive agreement for both construction and project management in contrast to 3% and 7% of disagreement. In addition, both groups rated the construction field close to the project management field.

As shown in section 4.2.3.5, both groups of PERFECT participants were asked to rate their perceptions about the intensity of different levels of possible factors that affected their performance. Similarly, both groups identified the "learning from mistakes" factor as the main factor that affected their performance. Similar to conclusions derived from VICE, this emphasizes the effectiveness of the repeatability aspect of simulations, which navigate participants through different possible scenarios and provide necessary information on different subjects. In addition, "learning from mistakes" obtained the highest "Excellent help" percentage among all factors for both groups. As expected, Group A, which had basic project time management knowledge before simulation, stated "Prior knowledge from classroom instruction" as the second most effective factor, whereas Group B specified "Instructions within the simulation" as the next important factor after "learning from mistakes."

Although both participant groups demonstrated that simulations can be "Excellent help" or "Much help" in learning real-world construction projects, the college students showed a higher agreement level. This pattern existed when both groups expressed a level of agreement when rating that simulations and project-based learning delivery are more effective ways than traditional lecture-based methods. Similarly, when participants rated if they thought that project-based learning methods and simulations should be integrated with construction curricula, college students demonstrated a higher level of agreement.

Sixty percent of participants in Group A and 70 percent in Group B believed that "A lot" or "Most everything" about project time management could be learned through simulation, although neither Group A nor Group B specified any preference for using simulation over traditional lectures in learning project management. Finally, Group A stated a different opinion from Group B about integration of simulation-based learning throughout the construction program curricula. In Group A, 27 percent of participants specified "Totally Disagree" or "Disagree" on the integration, whereas 26 percent selected "Agree" or "Totally Agree" levels. In Group B, these two numbers were 20 and 50 percent, respectively.

- *What is the effect of simulation on the level of participants' engagement?*

Level of engagement was measured numerically for both groups of PERFECT participants. A five-point level scale was used to capture the participants' self-evaluation. Both groups demonstrated an above-average level of engagement. However, in open-ended questions, participants mentioned a few factors to increase the level of engagement such as having more exciting narrations, more animations, and/or more interactive features.

- *What is the relationship between the actual performance of participants and their perceptions about content knowledge gained?*

Based on the subject, the questions provided in Pre-Quiz and the main simulation of PERFECT were categorized into four areas so that the actual performance measurement of participants was investigated by comparing the pre- and post-simulation data of these areas. In Post-Survey, participants were asked to rate their perceived knowledge gained in the same four areas. As shown in the PERFECT results section, the t test results indicated there was a meaningful difference between the pre and post-test knowledge gained scores at a significance level of 0.05 for both Groups A and B. Analogously, similar t test results of Post-Survey showed a meaningful difference between the pre and post-test perceived knowledge gained scores at a significance level of 0.05 for both Groups A and B. This indicates a co-occurrence between the actual performance of participants and their perceptions about content knowledge gained.

5.2 LIMITATIONS

Since the main objective of this research was to explore the outcomes of using simulation in construction education, both VICE and PERFECT simulation applications were designed, developed, and tested to achieve this objective. Then, the data gathered were analyzed, and the results and associated interpretations were discussed. However, limitations of the context and practical approach used should be incorporated into the findings of this project. The main limitations of both applications are provided in the section below:

One major problem in measuring the effectiveness of simulations in education is the lack of standardized assessment tools. This issue is more obvious in construction education because of the vast arrays of construction topics. This highlights the role of subjective decisions in designing measurement structures and plans. In addition to the lack of standardized assessment tools, measuring the learning process through a single group pre-test and post-test design has become dominant. Although this is a common and acceptable approach in educational research, it suffers from lack of randomization and, thus, changes the research experiment project to a quasi-experimental research one. This eliminates the possibility of having control groups and performing a comparison between control and experiment group data. Therefore, generalization of findings would have a lower degree of certainty. Another challenge of simulation application is the dilemma of choosing between the simulation engagement and results reliability. In the measurement processes, a design with more questions on actual performance will result in covering a larger variety of questions and providing more data, and, therefore, more reliable analyses. On the other hand, increasing the test portion of the simulation decreases the level of engagement because the simulation application converts from a fun and engaging activity to a mandatory computerized tool. Thus, finding an appropriate balance requires further research. Practically, this opportunity is not available in most cases.

Another challenge in measuring simulation effectiveness is its short duration; all the data regarding the performance has to be gathered through a session held in a few hours. The introduction, application training, simulation questions, and a final survey, all occur in a single session. Therefore, there is a risk that the data do not represent the whole learning process.

Finally, measuring the difference between pre and post simulation is difficult. If the questions provided in the Pre-Quiz section are identical to those presented in the main simulation, there is a memorizing risk, and the reliability of data would be endangered. In contrast, providing similar, but not identical, questions would affect the data validity.

5.3 RECOMMENDATIONS

Based on the experience gained through the implementation of VICE and PERFECT applications, these recommendations can be considered:

- Specifying of research objectives for users

If simulation participants have a clear understanding of the research objectives, their collaboration will be increased, and they can better express their thoughts and opinions in different stages of simulation. This improves the quality of feedback and enhances the project outcomes.

- Setting of simulation goals, limitations, and incentives

Educational games and simulations should set specific goals, limitations and incentives for participants. Having a clear map helps participants to construct mental models and focus on performance instead of stumbling around different modules and trying to build mental models using unrelated elements.

- Focus of simulation

Experience of VICE is representative of a wide range of subjects covered in less depth. PERFECT, in contrast, with a narrower range of subjects covered in greater depth, indicated that simulations with specific and limited focus result in more reliable outcomes. The latter types of simulations take advantage of standard tools and methods. In addition, they provide more precise outcomes. Moreover, these simulation applications can be designed and implemented through different phases.

- Intricate pattern

Revealing simple or linear patterns in management simulations demotivates participants, and hinders them from discovering the game rules and using innovative efforts. Multi-layer, albeit not complex, patterns encourage participants to improve performance and gain better results.

- Level of difficulty

Since participants in simulations have different levels of subject knowledge or experience, providing different levels of difficulty engages more participants. It provides the opportunity for participants to select the level of simulation proportionate with their desires.

- Enhancing interactive patterns

Interactive elements and their features were of interest to participants in both VICE and PERFECT feedback. As expected, more interactive elements resulted in more participant engagement. Therefore, in designing simulation applications, enhancing interactive patterns should be one of the main criteria.

- Increase of user control

In order to present engaging educational games and create an interaction between the users and simulation, the control over the application should be conferred as much as possible on the participants. This keeps the attention of participants during simulation.

- Standard sets of measurement

Using standard measurement sets allows simulation designers to reliably define the measurement data points. Thus, analyzed data will benefit from the support of standardized tools and methods. This also enables the researchers to compare the results with other published research.

- Data retrieving

The data capturing setting of the simulation should allow the participants to pause and resume the application at any given time. Adding this flexibility creates additional opportunities for students to participate at any time other than limited available times scheduled in regular class timeframes. Additionally, in case any glitch happens, the data will not be lost. Therefore, the data retrieving mechanism should fully support all possible scenarios.

5.4 DIRECTIONS FOR FUTURE RESEARCH

This research provided findings from two simulation applications in construction management education. In order to advance achievement of this project, further research is required. Both VICE and PERFECT applications were designed, developed, and implemented within a limited frame of time and cost; thus, there is an opportunity to enrich these two applications by providing in-depth materials, like educational modules, or more engaging components such as interactive animations. In addition, to fortify the results, the simulation participants can include a control group. This allows comparison between the results of experiment groups with control groups in terms of effectiveness, engagement, time spent, and so on. Another possible research direction is providing other modules with different subject areas. For example, while VICE focused on a single span bridge project, future modules can include residential building, commercial building, and heavy construction. This allows for comprehensive simulation applications that cover various aspects of construction projects. As another example, any other knowledge areas of PMBOK can be the next subject of application as a complementary module besides PERFECT. It would be valuable for construction programs to provide all of the knowledge areas of the project management standard as a simulation application. Another direction of future research can consider collaboration and communication as the main feature of simulation. This enriches the quality of VICE or PERFECT from solely individual-based applications to collaborative ones. Specifically, with the advent of online and real-time applications, this feature helps the educational games to keep up with current gaming trends. Another direction of future research would be to consider the specialization of simulation based on age level, construction knowledge level, and gender.

5.5 SUMMARY

Educational games and simulations are growing rapidly in many fields. They yield repeatable experiences incorporating innovative methods for solving real-world problems. Simulations are currently considered rich supplementary materials in pedagogy. In construction, this trend has evolved, albeit later than some disciplines. Numerous issues such as cost, risk, time, effectiveness, and repeatability existing in the construction academic environment make simulations appealing and reasonable educational materials. As shown in the interpretation section, both VICE and PERFECT are examples of simulations in construction. Both were effective and engaging. The results of both applications indicated that there was a significant difference between the mean of pre and post-test scores of perceived content knowledge gained. Although student perceptions of learning are typically considered as a practical direct measurement of learning, using pre and post simulation experiment comparisons strengthens the results. A comparison between pre and post actual performance of participants revealed a significant difference for both VICE and PERFECT applications. However, there were a number of limitations in design and development processes that hampered the results' generalization. Lack of a control group and difficulty of random selection of subjects are major problems in simulation tests. A standard set of tools like those used in PERFECT improve the validity of the results. Results of VICE and PERFECT demonstrate the benefit of simulation applications in helping students to learn more about construction project management and to increase their interest and motivation in learning construction management. Future modules of simulation applications should include other aspects of construction project management such as cost, scope, risk, human resources, etc. Then, all these simulation applications will be capable of providing the necessary knowledge and skills for students in construction programs.

In conclusion, although this study may not have fully represented the effects of the simulations on participants' learning, it provides evidence that students in a construction program emphasized the merit of construction project management simulation applications as effective educational tools to increase their engagement and construction project management knowledge.

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APPENDIX A: CNST 4850 SYLLABUS

CNST 4850
CONSTRUCTION PROJECT SCHEDULING AND CONTROLS
FALL 2013
SYLLABUS

Assigned Text:
Construction Planning and Scheduling by Jimmie W. Hinze Second Edition (or newer)
Step by Step: Microsoft Project 2013 by Carl Chatfield, and Timothy Johnson

Course Description:
Planning and scheduling a construction project using the critical path methods (CPM) and Linear Scheduling. You will be learning how to plan, schedule, and monitor a construction project using concepts such as project pre-planning, logic networks, network construction, time estimates, critical path, float time, crash programs, costs, short interval scheduling, earned values, etc. Computerized scheduling techniques will be introduced, also.

Course Objective:
To provide the students with basics, concepts, and tools to understand and perform the planning and scheduling operations, which are vital to the success of all construction projects.

Attendance:
A great deal of what will be expected from you on assignments and covered on exams will be discussed in length during class hours. Students are expected to contribute every class individually and as part of a team. For those reasons, you are expected to attend class every session. There will be a lot of information covered each class. However you are responsible to manage your own time. You are going to be treated as professional, working adults, and for this reason you are expected to attend all classes as if it were your job. Each unexcused absence will result in the deduction of 2 points from your final grade. More than five absences will result in an automatic failing grade, unless you are able to drop the course, first. If you are late, you will be considered absent. One second beyond 7:30 AM is considered late. Plan to be in class 10 minutes early to avoid problems.

Homework:
Homework will consist of a series of questions, problems and projects, to be assigned on an as necessary basis.

- All literary documents must be completed using Word and will be graded for content, grammar, spelling, etc. **Hand written assignments will not be accepted.**
- Numeric tables must be completed using Excel.
- Math problems must be printed neatly and in logical order on engineering paper.
- Diagrams must be ***drafted neatly*** on engineering graph paper using pencil and a straight edge.
- You will be expected to hand in a hard copy of all written assignments unless instructed differently.

- All homework assignments are due at the beginning of the designated class.
- Assignments not completed per these requirements will ***not*** be accepted.
- All late homework will be assessed liquidated damages of 5 points per day.
- No late assignments will be accepted after the assignment has been returned to the students.
- You are expected to read the assigned chapters before coming to class. Any information contained in the reading material is fair game for quizzes.

Computer Usage:
All literary documents will be completed using Word. You will be expected to hand in a hard copy of all written assignments. All numeric tables should be completed on Excel. Introduction to scheduling software will be conducted during the semester. Students should follow the tutorial provided with the software and the text, learning to use the program, and bringing any questions or problems to class. Students are responsible for understanding how to use the UNO Blackboard system, and will be responsible for all announcements, assignments, course changes, etc. which are posted there. Students are also responsible for any email transmitted to the email account which is listed for them on Blackboard.

Quizzes and Exams:
The number and type of quizzes is at the discretion of the instructor, but you can generally expect one per week. These are meant to test your understanding of the reading and presentation topics. There will typically be three or four exams during the semester. Quizzes may or may not be announced. Exams will be announced a week prior. There are no makeup quizzes or exams.

Cheating/Plagiarism:
Cheating and plagiarism will not be tolerated. I fully expect you to work ***with*** your classmates when studying and learning to solve problems. You are not helping yourself or your classmates by copying someone else's work, or allowing someone to copy yours. If you are caught, ***all*** parties involved will receive a zero for that assignment and may risk being removed from the class.

Final Project:
There will be a course project which will be described in detail in the coming weeks. The final presentation may be scheduled during the week before finals. This will be decided later.

Grading Framework:

Activity	Points per Item
Homework Assignments	25
Exams	100
Quizzes	25
Final Project	100

The above points will account for 90% of your final grade. The last 10% will be at the professor's discretion. It will include such factors as participation, preparation, and attitude. Absences will be penalized against the final grade.

Class Policies:
No Eating
No Spitting Tobacco
Drinks should be in securely covered, resealable containers
No hats worn
No cell phones

Blackboard
Blackboard will be used throughout the semester to post grades, assignments, notes, etc. You will be responsible for printing handouts required or desired for class.

Supplementary Materials: TBA

Please note: This is a living document and therefore subject to change or revision.

Please further note: You are responsible for reading the material prior to coming to class. You are also responsible for coming to class on time and prepared to discuss the day's topic.

Please note further than the previous note: You will be treated as professional working adults in this class with all the trappings and responsibilities attached to that dubious honor. Please conduct yourselves appropriately.

Please note this one last thing, unless I think of something later on: We are actually going to attempt to have fun while learning in this class, so please be prepared to have a good time and not take life too seriously.

Proposed Topics:

- Network Diagrams
- Precedence Diagrams
- Determining Activity Durations
- Time in Contract Provisions
- Resource Allocation
- Resource Leveling
- Money and Network Schedules
- Computer Scheduling
- Earned Value
- Impact of Scheduling Decisions
- Short Interval Schedules
- Linear Scheduling
- Computer Scheduling

APPENDIX B: THE DURHAM SCHOOL ENROLLMENT STATISTICS

DSAEC fall enrollment statistics 2008-2012

Level	Programs/Campus	Fall 2008	Fall 2009	Fall 2010	Fall 2011	Fall 2012	Fall 2013
Undergraduate	Architectural Engineering (Omaha)	221	224	221	204	172	169
	Construction Engineering (Omaha)	49	42	45	40	36	25
	Construction Engineering (Lincoln)	-	-	-	-	-	12
	Construction Management (Omaha)	85	98	107	103	94	86
	Construction Management (Lincoln)	268	240	206	182	154	149
Master	Architectural Engineering	44	53	41	49	44	47
	Construction	-	-	7	6	10	6
Ph.D.	Architectural Engineering	5	16	17	19	20	19
	Construction	-	-	16	20	17	19

Table 2: DSAEC first year fall enrollment statistics 2008-2012

	Fall 2008	Fall 2009	Fall 2010	Fall 2011	Fall 2012	Fall 2013
Architectural Engineering (Omaha)	62	58	52	64	44	34
Construction Engineering (Omaha)	11	7	6	8	6	3
Construction Engineering (Lincoln)						6
Construction Management (Omaha)	13	15	19	10	7	5
Construction Management (Lincoln)	17	11	14	12	7	13

Table 3: CNST 4850 enrolled students in 2013 & 2014

Program	Level	Fall 2013	Fall 2014
Construction Engineering	Sophomore	-	-
	Junior	1	-
	Senior	-	2
Construction Management	Sophomore	1	-
	Junior	2	3
	Senior	20	16

APPENDIX C: INFORMED CONSENT FORM

University of Nebraska Lincoln

IRB Approval
IRB# 20140914606 EX
Date Approved: 09/11/2014
Valid Until: 09/10/2019

Title of study: Project-oriented Educational Research Fostering Excellence in Cyber-infrastructure Teaching (PERFECT)

Principal investigator: Saeed Rokooei

Co-PI: Dr. James Goedert, jgoedert1@unl.edu, 402-554-4047

Institute: Durham School of Architectural Engineering and Construction, University of Nebraska – Lincoln

Introduction: The following research study addresses the teaching of the interdisciplinary area of project management using Cyberinfrastructure tools for development and content delivery. In order to address this problem, undergraduate students declared as a Construction major are invited to participate in the completion of a learning styles questionnaire.

Background information: This research is a project-oriented interactive simulation using previously developed research methods, tools and a real world project for one of the ten knowledge areas defined by the Guide to the Project Management Body of Knowledge (PMBOK® Guide). This simulation will be tested for engagement and effectiveness in project-oriented courses in Engineering and Information Sciences.

Purpose of this research study: The overall goal of this research proposal is to develop an effective and engaging project-oriented simulation to teach one area of the project management curriculum as developed by the Project Management Institute (PMI) to enhance undergraduate education at the University of Nebraska.

Procedures: Participation in the study will require approximately 120 minutes of your time and will consist of completing a learning styles questionnaire and the PERFECT application.

Risks and/or Discomforts: There are no known risks or discomforts associated with this research.

Benefits: Participants in this research will learn the concepts of project time management based on Guide to the Project Management Body of Knowledge (PMBOK® Guide). In addition, will show the effectiveness of using simulation for project management education.

Right of refusal to participate and withdrawal: You, the student, are free to decide not to participate in this study. You can also withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln.

Confidentiality: The information provided by you will remain confidential. Nobody except principal investigator will have an access to it. Your name and identity will also not be disclosed at any time. However the data may be seen by an ethical review committee and may be published in journal and elsewhere without giving your name or disclosing your identity.

Available Sources of Information: If you have additional questions you may contact Principal Investigator Saeed Rokooei, Durham School of Architectural Engineering and Construction, the University of Nebraska - Lincoln via email, srokooei@unomaha.edu. If you have any questions or concerns about the research, you should contact the IRB Office at 402-472-6965 or irb@unl.edu.

UNIVERSITY OF Nebraska Lincoln

IRB# 20140914606 EX
Date Approved: 09/11/2014
Valid Until: 09/10/2019

Consent, Right to Receive a Copy: You are voluntarily making a decision whether or not to participate in this study. Your completion of the survey certifies that you have decided to participate having read and understood the information presented.

Signature of Participant:

______________________________ ______________________________

Signature of Research Participant Date

Name and Phone number of investigator(s)

Saeed Rokooei:	(402)612-8380
James Goedert, Ph. D.,:	(402)554-4047

APPENDIX D: PRE AND POST-TEST SCORES IN PERFECT

Group A actual performance paired samples statistics (37 Questions)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	O1	3.50	30	1.042	.190
	P1	3.90	30	.305	.056
Pair 2	Q2	2.30	30	1.466	.268
	P2	3.87	30	.434	.079
Pair 3	Q3	2.70	30	1.343	.245
	P3	3.13	30	.973	.178
Pair 4	Q4	2.13	30	1.224	.224
	P4	3.33	30	.959	.175
Pair 5	Q5	3.10	30	1.029	.188
	P5	3.63	30	.615	.112
Pair 6	Q6	1.80	30	1.064	.194
	P6	2.77	30	1.104	.202
Pair 7	Q7	3.07	30	1.202	.219
	P7	3.60	30	.814	.149
Pair 8	Q8	1.93	30	1.172	.214
	P8	3.33	30	.922	.168
Pair 9	Q9	3.03	30	.964	.176
	P9	3.87	30	.346	.063
Pair 10	Q10	3.40	30	1.003	.183
	P10	3.93	30	.365	.067
Pair 11	Q11	2.43	30	1.135	.207
	P11	3.60	30	.621	.113
Pair 12	Q12	3.80	30	.610	.111
	P12	3.97	30	.183	.033

Pair 13	Q13	1.63	30	1.033	.189
	P13	3.00	30	1.114	.203
Pair 14	Q14	2.97	30	1.129	.206
	P14	3.43	30	.971	.177
Pair 15	Q15	2.73	30	1.202	.219
	P15	3.40	30	1.037	.189
Pair 16	Q16	2.77	30	1.278	.233
	P16	3.13	30	1.074	.196
Pair 17	Q17	2.20	30	1.126	.206
	P17	3.37	30	.928	.169
Pair 18	Q18	2.97	30	1.189	.217
	P18	3.47	30	.681	.124
Pair 19	Q19	3.47	30	.776	.142
	P19	3.80	30	.407	.074
Pair 20	Q20	3.33	30	1.184	.216
	P20	3.87	30	.346	.063
Pair 21	Q21	2.50	30	1.253	.229
	P21	3.53	30	.681	.124
Pair 22	Q22	2.53	30	1.279	.234
	P22	3.23	30	1.040	.190
Pair 23	Q23	2.83	30	1.117	.204
	P23	3.27	30	.907	.166
Pair 24	Q24	3.70	30	.702	.128
	P24	3.77	30	.679	.124
Pair 25	Q25	2.33	30	1.269	.232
	P25	3.33	30	.959	.175
Pair 26	Q26	2.97	30	1.217	.222
	P26	3.53	30	.730	.133

Pair 27	Q27	3.37	30	.964	.176
	P27	3.90	30	.305	.056
Pair 28	Q28	3.80	30	.664	.121
	P28	4.00	30	.000	.000
Pair 29	Q29	3.07	30	1.202	.219
	P29	3.63	30	.718	.131
Pair 30	Q30	3.63	30	.850	.155
	P30	3.87	30	.346	.063
Pair 31	Q31	3.57	30	.971	.177
	P31	3.80	30	.484	.088
Pair 32	Q32	2.80	30	1.095	.200
	P32	3.53	30	.860	.157
Pair 33	Q33	2.30	30	1.343	.245
	P33	3.30	30	.794	.145
Pair 34	Q34	1.83	30	1.020	.186
	P34	2.53	30	1.137	.208
Pair 35	Q35	3.27	30	1.112	.203
	P35	3.43	30	.858	.157
Pair 36	Q36	3.57	30	1.040	.190
	P36	3.97	30	.183	.033
Pair 37	Q37	2.33	30	1.184	.216
	P37	3.50	30	.777	.142
Pair 38	Q38	3.50	30	1.042	.190
	P38	3.73	30	.828	.151
Pair 39	Q39	3.20	30	1.031	.188
	P39	3.57	30	.817	.149
Pair 40	Q40	3.20	30	1.095	.200
	P40	3.60	30	.770	.141

Group A actual performance paired samples t test (37 Questions)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Q1 - P1	-.400	1.037	.189	-.787	-.013	-2.112	29	.043
Pair 2	Q2 - P2	-1.567	1.478	.270	-2.119	-1.015	-5.805	29	.000
Pair 3	Q3 - P3	-.433	1.501	.274	-.994	.127	-1.581	29	.125
Pair 4	Q4 - P4	-1.200	1.606	.293	-1.800	-.600	-4.093	29	.000
Pair 5	Q5 - P5	-.533	.900	.164	-.869	-.197	-3.247	29	.003
Pair 6	Q6 - P6	-.967	1.299	.237	-1.452	-.481	-4.075	29	.000
Pair 7	Q7 - P7	-.533	1.074	.196	-.934	-.132	-2.719	29	.011
Pair 8	Q8 - P8	-1.400	1.163	.212	-1.834	-.966	-6.595	29	.000
Pair 9	Q9 - P9	-.833	.986	.180	-1.201	-.465	-4.631	29	.000
Pair 10	Q10 - P10	-.533	.973	.178	-.897	-.170	-3.002	29	.005
Pair 11	Q11 - P11	-1.167	1.053	.192	-1.560	-.773	-6.067	29	.000
Pair 12	Q12 - P12	-.167	.648	.118	-.409	.075	-1.409	29	.169
Pair 13	Q13 - P13	-1.367	1.273	.232	-1.842	-.891	-5.882	29	.000
Pair 14	Q14 - P14	-.467	1.224	.224	-.924	-.010	-2.088	29	.046
Pair 15	Q15 - P15	-.667	1.561	.285	-1.250	-.084	-2.339	29	.026
Pair 16	Q16 - P16	-.367	1.426	.260	-.899	.166	-1.408	29	.170
Pair 17	Q17 - P17	-1.167	1.704	.311	-1.803	-.531	-3.751	29	.001
Pair 18	Q18 - P18	-.500	1.225	.224	-.957	-.043	-2.236	29	.033
Pair 19	Q19 - P19	-.333	.884	.161	-.663	-.003	-2.065	29	.048
Pair 20	Q20 - P20	-.533	1.196	.218	-.980	-.087	-2.443	29	.021
Pair 21	Q21 - P21	-1.033	1.326	.242	-1.528	-.538	-4.269	29	.000
Pair 22	Q22 - P22	-.700	1.368	.250	-1.211	-.189	-2.802	29	.009

Pair 23	Q23 - P23	-.433	1.382	.252	-.949	.083	-1.718	29	.097
Pair 24	Q24 - P24	-.067	1.015	.185	-.446	.312	-.360	29	.722
Pair 25	Q25 - P25	-1.000	1.313	.240	-1.490	-.510	-4.171	29	.000
Pair 26	Q26 - P26	-.567	1.223	.223	-1.023	-.110	-2.538	29	.017
Pair 27	Q27 - P27	-.533	.900	.164	-.869	-.197	-3.247	29	.003
Pair 28	Q28 - P28	-.200	.664	.121	-.448	.048	-1.649	29	.110
Pair 29	Q29 - P29	-.567	1.223	.223	-1.023	-.110	-2.538	29	.017
Pair 30	Q30 - P30	-.233	.728	.133	-.505	.038	-1.756	29	.090
Pair 31	Q31 - P31	-.233	1.006	.184	-.609	.142	-1.270	29	.214
Pair 32	Q32 - P32	-.733	1.081	.197	-1.137	-.330	-3.717	29	.001
Pair 33	Q33 - P33	-1.000	1.509	.275	-1.563	-.437	-3.631	29	.001
Pair 34	Q34 - P34	-.700	1.579	.288	-1.290	-.110	-2.428	29	.022
Pair 35	Q35 - P35	-.167	1.085	.198	-.572	.239	-.841	29	.407
Pair 36	Q36 - P36	-.400	1.070	.195	-.800	.000	-2.048	29	.050
Pair 37	Q37 - P37	-1.167	1.147	.209	-1.595	-.738	-5.570	29	.000
Pair 38	Q38 - P38	-.233	1.104	.202	-.646	.179	-1.157	29	.257
Pair 39	Q39 - P39	-.367	1.351	.247	-.871	.138	-1.486	29	.148
Pair 40	Q40 - P40	-.400	1.163	.212	-.834	.034	-1.884	29	.070

Group B actual performance paired samples statistics (37 Questions)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Q1	3.10	30	1.348	.246
	P1	3.77	30	.626	.114
Pair 2	Q2	2.13	30	1.432	.261
	P2	3.70	30	.702	.128
Pair 3	Q3	2.57	30	1.278	.233
	P3	3.10	30	1.029	.188
Pair 4	Q4	2.30	30	1.208	.221
	P4	3.60	30	.855	.156
Pair 5	Q5	3.20	30	1.031	.188
	P5	3.63	30	.718	.131
Pair 6	Q6	1.57	30	1.135	.207
	P6	2.60	30	1.429	.261
Pair 7	Q7	2.87	30	1.332	.243
	P7	3.70	30	.702	.128
Pair 8	Q8	2.00	30	1.259	.230
	P8	3.07	30	.868	.159
Pair 9	Q9	2.83	30	.950	.173
	P9	3.47	30	.776	.142
Pair 10	Q10	3.47	30	.900	.164
	P10	3.77	30	.679	.124
Pair 11	Q11	2.13	30	1.224	.224
	P11	3.33	30	.884	.161
Pair 12	Q12	3.27	30	1.015	.185
	P12	3.80	30	.551	.101
Pair 13	Q13	1.67	30	1.155	.211
	P13	2.90	30	1.125	.205

Pair 14	Q14	2.23	30	1.251	.228
	P14	3.33	30	.922	.168
Pair 15	Q15	2.87	30	1.196	.218
	P15	3.17	30	1.053	.192
Pair 16	Q16	2.33	30	1.322	.241
	P16	2.97	30	1.066	.195
Pair 17	Q17	1.90	30	1.029	.188
	P17	3.40	30	.968	.177
Pair 18	Q18	2.73	30	1.311	.239
	P18	3.43	30	.935	.171
Pair 19	Q19	3.30	30	.915	.167
	P19	3.87	30	.571	.104
Pair 20	Q20	2.77	30	1.331	.243
	P20	3.50	30	.938	.171
Pair 21	Q21	1.73	30	1.081	.197
	P21	2.90	30	1.242	.227
Pair 22	Q22	2.93	30	1.112	.203
	P22	3.17	30	1.020	.186
Pair 23	Q23	2.23	30	1.331	.243
	P23	2.80	30	1.186	.217
Pair 24	Q24	2.30	30	1.208	.221
	P24	3.53	30	.730	.133
Pair 25	Q25	2.27	30	1.202	.219
	P25	2.73	30	1.048	.191
Pair 26	Q26	1.97	30	1.189	.217
	P26	3.27	30	.907	.166
Pair 27	Q27	2.37	30	1.299	.237
	P27	3.73	30	.691	.126

Pair 28	Q28	2.70	30	1.343	.245
	P28	3.63	30	.765	.140
Pair 29	Q29	2.20	30	1.064	.194
	P29	3.00	30	1.145	.209
Pair 30	Q30	2.60	30	1.329	.243
	P30	3.30	30	1.055	.193
Pair 31	Q31	2.50	30	1.225	.224
	P31	3.67	30	.711	.130
Pair 32	Q32	2.33	30	1.155	.211
	P32	3.67	30	.758	.138
Pair 33	Q33	1.97	30	1.273	.232
	P33	3.00	30	1.114	.203
Pair 34	Q34	1.73	30	1.081	.197
	P34	2.67	30	1.093	.200
Pair 35	Q35	2.27	30	1.230	.225
	P35	3.40	30	.855	.156
Pair 36	Q36	3.80	30	.610	.111
	P36	3.77	30	.568	.104
Pair 37	Q37	2.57	30	1.165	.213
	P37	3.23	30	1.104	.202
Pair 38	Q38	3.30	30	1.208	.221
	P38	3.73	30	.691	.126
Pair 39	Q39	2.63	30	1.189	.217
	P39	3.33	30	.802	.146
Pair 40	Q40	3.07	30	1.285	.235
	P40	3.70	30	.794	.145

Group B actual performance paired samples t test (37 Questions)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Q1 - P1	-.667	1.155	.211	-1.098	-.235	-3.162	29	.004
Pair 2	Q2 - P2	-1.567	1.357	.248	-2.073	-1.060	-6.326	29	.000
Pair 3	Q3 - P3	-.533	1.592	.291	-1.128	.061	-1.835	29	.077
Pair 4	Q4 - P4	-1.300	1.442	.263	-1.838	-.762	-4.938	29	.000
Pair 5	Q5 - P5	-.433	.898	.164	-.769	-.098	-2.644	29	.013
Pair 6	Q6 - P6	-1.033	1.326	.242	-1.528	-.538	-4.269	29	.000
Pair 7	Q7 - P7	-.833	1.367	.250	-1.344	-.323	-3.340	29	.002
Pair 8	Q8 - P8	-1.067	1.484	.271	-1.621	-.513	-3.937	29	.000
Pair 9	Q9 - P9	-.633	.999	.182	-1.007	-.260	-3.471	29	.002
Pair 10	Q10 - P10	-.300	1.055	.193	-.694	.094	-1.557	29	.130
Pair 11	Q11 - P11	-1.200	1.495	.273	-1.758	-.642	-4.397	29	.000
Pair 12	Q12 - P12	-.533	1.042	.190	-.922	-.144	-2.804	29	.009
Pair 13	Q13 - P13	-1.233	1.888	.345	-1.938	-.528	-3.578	29	.001
Pair 14	Q14 - P14	-1.100	1.517	.277	-1.666	-.534	-3.973	29	.000
Pair 15	Q15 - P15	-.300	1.489	.272	-.856	.256	-1.104	29	.279
Pair 16	Q16 - P16	-.633	1.542	.282	-1.209	-.057	-2.249	29	.032
Pair 17	Q17 - P17	-1.500	1.456	.266	-2.044	-.956	-5.642	29	.000
Pair 18	Q18 - P18	-.700	1.535	.280	-1.273	-.127	-2.498	29	.018
Pair 19	Q19 - P19	-.567	1.006	.184	-.942	-.191	-3.084	29	.004
Pair 20	Q20 - P20	-.733	1.461	.267	-1.279	-.188	-2.750	29	.010
Pair 21	Q21 - P21	-1.167	1.487	.272	-1.722	-.611	-4.296	29	.000
Pair 22	Q22 - P22	-.233	1.501	.274	-.794	.327	-.851	29	.402

Pair 23	Q23 - P23	-.567	1.716	.313	-1.207	.074	-1.809	29	.081
Pair 24	Q24 - P24	-1.233	1.331	.243	-1.730	-.736	-5.076	29	.000
Pair 25	Q25 - P25	-.467	1.756	.321	-1.123	.189	-1.455	29	.156
Pair 26	Q26 - P26	-1.300	1.208	.221	-1.751	-.849	-5.896	29	.000
Pair 27	Q27 - P27	-1.367	1.351	.247	-1.871	-.862	-5.539	29	.000
Pair 28	Q28 - P28	-.933	1.285	.235	-1.413	-.454	-3.979	29	.000
Pair 29	Q29 - P29	-.800	1.375	.251	-1.313	-.287	-3.188	29	.003
Pair 30	Q30 - P30	-.700	1.601	.292	-1.298	-.102	-2.395	29	.023
Pair 31	Q31 - P31	-1.167	1.416	.259	-1.696	-.638	-4.512	29	.000
Pair 32	Q32 - P32	-1.333	1.295	.237	-1.817	-.850	-5.637	29	.000
Pair 33	Q33 - P33	-1.033	1.629	.297	-1.642	-.425	-3.474	29	.002
Pair 34	Q34 - P34	-.933	1.721	.314	-1.576	-.291	-2.971	29	.006
Pair 35	Q35 - P35	-1.133	1.525	.278	-1.703	-.564	-4.070	29	.000
Pair 36	Q36 - P36	.033	.809	.148	-.269	.335	.226	29	.823
Pair 37	Q37 - P37	-.667	1.322	.241	-1.160	-.173	-2.763	29	.010
Pair 38	Q38 - P38	-.433	.817	.149	-.738	-.128	-2.904	29	.007
Pair 39	Q39 - P39	-.700	1.317	.240	-1.192	-.208	-2.911	29	.007
Pair 40	Q40 - P40	-.633	1.189	.217	-1.077	-.190	-2.919	29	.007