EXPLORING THE EFFECTIVENESS OF DIGITAL GAMES IN PRODUCING PRO-ENVIRONMENTAL ATTITUDES AND BEHAVIORS

by

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Dedicated to my family

I dedicate my dissertation to my husband, children, parents, and siblings. My husband, our son and daughter have been my pillars of strength and support throughout my doctoral journey, although it was late in my career. Never once did they doubt my ability to complete it despite several challenges I had to face. That gave me the strength to persist and reach this stage. I am grateful to my parents for giving me a quality education from my first year in Kindergarten. I owe them all deep felt gratitude in shaping my thoughts and dreams.

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ABSTRACT

This dissertation consists of three journal articles that explored the effectiveness of a digital game, called EnerCities, in producing pro-environmental attitudes and behaviors by using a mixed-methods study approach. The first study was conducted as a quasi-experimental study among undergraduate students in the United States. Based on the Attitudinal Learning Instrument (ALI), this study found that the attitudinal learning gained from EnerCities influenced participants' pro-environmental behavioral intentions significantly. This learning was retained until five weeks after game play according to the qualitative results of the study. The second study, conducted in India, used EnerCities to study the differences in attitudinal learning among high school students who played the game collaboratively or individually, using the ALI and Theory of Planned Behavior (TPB). Results showed that the attitudinal learning and its effect on pro-environmental behavioral intentions between collaborative and individual players was similar. This study also showed that EnerCities had significantly impacted the environmental attitudes and behaviors of the game players when compared to students who did not play any game, although all students had studied environmental studies through traditional instructional methods since elementary school. The third study, conducted among high school students in India, compared the environmental attitudes between game players and students who did not play any game based on the New Ecological Paradigm (NEP) scale. Both the unidimensional and multi-dimensional properties of the NEP were considered. It was found that EnerCities had impacted game players' environmental attitudes significantly. All the three studies showed that digital games are more effective in promoting attitudinal (cognitive, affective, behavioral and social) learning compared to traditional instructional methods. This supports the implementation of digital games as a pedagogical tool in influencing environmental attitudes and behaviors.

CHAPTER 1. INTRODUCTION

Environmental degradation and climate change impact the lives of animals, plants, their habitats and ecosystems (Root et al., 2003; NOAA, 2018) and cause zoonotic transmission of diseases, such as COVID-19, to human beings because of habitat collapse (UNEP, 2020). However, people fail to recognize that the main cause is human induced (anthropocentric) changes to the environment and atmospheric composition. Such activities include burning fossil fuels, rapid urbanization leading to concrete jungles, and land use changes (Karl & Trenberth, 2003; Meya & Eisenack, 2018; UNEP, 2020). Although sustainability education creates awareness, that knowledge does not encourage pro-environmental attitudes and behaviors in the real world (Hungerford & Volk, 1990; Rideout, 2005; Hodgkinson & Innes, 2000; Vorkinn & Riese, 2001).

Attitudinal instruction specifically designed to teach environmental sustainability to young learners is needed so that they can learn to sacrifice some of their wants and desires now to ensure a better future (Fielding & Head, 2012; Nickerson, 2003). Sustainability education must create awareness (Buchanan et al., 2016; Huckle, 2012), should promote mindfulness (Wang et al., 2019), and be persuasive in order to change attitudes and behaviors (Griset, 2010; Sinatra et al., 2012), be interactive (Meya & Eisenack, 2018) and be adapted to the needs of young learners. There is a need to provide learners with skills in decision-making, and promote a sense of ownership and empowerment, which will translate as behavioral changes that support environment sustainability (Hungerford & Volk, 1990). Hence, the solution is creating feelings of empathy and encouraging learners to perform an action that is slightly different from their existing attitude and slightly matching the target attitude (Kamradt & Kamradt, 1999). UNESCO (n.d) states that "learning in an interactive, learner-centred way that enables exploratory, action oriented and transformative learning," would inspire learners to act sustainably. Using videos and print media stop with providing cognitive knowledge (Hungerford & Volk, 1990) and these conventional methods need to be replaced by a transformative pedagogy (Bell, 2016).

Gee (2008) emphasizes the need for knowledge to be provided as an activity and experience, and not just as facts and information, and to be situated in scenarios which help learners develop situated understandings. In environmental sustainability education, digital games satisfy all of the above conditions, and can serve as effective pedagogical tools (Cheng et al., 2013; Chen et al., 2019; Troussas et al., 2019) because they can encourage exploration and experimentation when

teachers and parents use them purposefully as "objects-to-think-with" (Holbert & Wilensky, 2019). Several studies have shown the growth in popularity of digital games among young learners across the globe (Statistica, 2018; Pew Research Center, 2018). It is wise to use this impactful tool as a persuasive pedagogical tool to teach young learners about correct attitudes and behaviors concerning environmental sustainability and other socio-scientific topics like, behaviors during pandemics, health, food, drug abuse, smoking and so on.

Research Purpose and Potential Significance

This dissertation is comprised of three mixed methods research studies that explored the effectiveness of digital game-based learning (DGBL) in producing pro-environmental attitudes and behaviors. The effectiveness of DGBL in attitudinal instruction in a K-12 school in India and in a university in the United States was studied using different survey instruments and data analysis methodologies. The quantitative strands of the mixed methods studies provided insights into whether DGBL was effective in producing pro-environmental attitudes and behaviors, while the qualitative strands provided insights into game play experience and why and how learners gained cognitive, affective, behavioral and social learning during and after playing the game. In addition, game features that facilitate attitudinal learning were listed from the studies that can be useful for designers of games for attitudinal instruction. Use of games in environmental sustainability education based on these studies may have implications for teaching other socio-scientific topics as well.

Researcher Worldview

Knowledge is power, no doubt, but what people do with knowledge is more important. Dr. Deborah Birx said on national television when the COVID-19 crisis started, "There is no magic bullet, there is no magic vaccine or therapy. It is just behavior." She was referring to wearing masks and social distancing to prevent infections from transmitting among people. We now know that by not following that advice we have lost lives, destroying families and livelihoods. Simple behaviors would have prevented this. This experience showed that changing behaviors is more challenging than imparting knowledge.

I have taught various subjects like Math, Physics, computer hardware and business organization; however, I found the greatest joy and satisfaction when teaching environmental studies (EVS) to middle school students in India. This was because I was not just providing knowledge, I was also trying to teach them correct attitudes and behaviors and preparing them for a sustainable future. I found that my learners were more interested in learning about the environment because they could easily connect it to their lives, and it was more relevant than learning quadratic equations or optics, for them.

It is my fervent belief that education should be relevant for it to impact learners' lives whether it means selecting a professional degree or planning careers or developing correct attitudes and behaviors. I did not know about learning theories, behavioral theories like the theory of planned behavior or the principles of attitudinal learning, hence my approach to instruction was by traditional means.

I wish that digital games had been available then because I believe DGBL is more powerful in attitudinal instruction because it makes learning authentic. It gives learners the freedom to test behaviors, see consequences and learn from mistakes. Giving similar experiences in traditional methods of instruction is not easy because it is not feasible and also because consequences in real life become visible only after a long time.

Advancements in technology have opened new avenues in numerous fields and have introduced emerging technologies like games, Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI) into education. Technology integration in education is still in its nascent stages owing to several bottlenecks like costs, time availability and lack of knowledge and expertise among instructors. However, using games in education is a little ahead compared to other technologies, and are more accessible and economical.

Several studies have examined the effectiveness of games in instruction and mixed results have been obtained. However, studies on attitudinal instruction using games are not common and hence I wanted to investigate the use of DGBL in environmental sustainability education. In most cases, learning may not produce long-term behavioral changes because learned environmental attitudes and behaviors are forgotten and inconvenient to practice (Arbuthnott, 2009; Hungerford & Volk, 1990; Tucker, 1999). Therefore, the goal of attitudinal instruction must be to influence all the three components of attitude: cognitive, affective and behavioral attitudes (Kamradt & Kamradt, 1999; Simonson, 1979) and social learning where interaction with others influences

attitudes, positively or negatively leading to attitudinal learning (Watson et al., 2018). If games are effective in attitudinal instruction then they must influence all the four components.

The three mixed methods studies that form my dissertation explored the effectiveness of DGBL in environmental sustainability education and endeavored to answer two overarching research questions: (1) Are digital games effective in producing pro-environmental attitudes and behaviors? (2) What were learners' perceptions of their game play experience and how did DGBL produce cognitive, affective, behavioral and social learning? In addition, each of the three studies answered other questions addressing learning retention over a five-week period, what features of the game helped in attitudinal learning, explanation of behaviors based on the theory of planned behavior (TPB; Ajzen, 2019) and whether the New Ecological Paradigm (NEP) survey was suitable for use in India among high school learners. The following section will provide an overview of the three studies.

Dissertation Structure and Chapter Highlights

This dissertation is divided into five chapters. The first chapter presents the goals of the dissertation, providing a brief introduction to the three studies and describing the importance of answering the research questions. The second, third and fourth chapters present the three research studies that comprise this dissertation. The fifith chapter discusses all three studies and outlines the conclusions that I drew from them to provide an argument in favor of using DGBL for environmental sustainability education aimed at attitudinal learning.

Chapter two describes Study one that was codnucted in a R1 university in the mid-western region of the United States among undergraduate students in an educational technology course. This mixed methods study was quasi-experimental with one group of students playing EnerCities, a game designed purposefully for environmental sustainability education and another group playing a game not connected to environmental sustainability. Chapter three explains Study two that describes a study conducted in a high school in Kozhikode in South India to explore the differences in attitudinal learning among learners who played EnerCities individually and learners who played EnerCities collaboratively in teams. This study also examined the differences between all game players and a control group of students who did not get the game intervention. All the participants were taught environmental sustainability education through traditional methods before EnerCities was introduced. Chapter four describes Study three that was conducuted among the

same participants from Study two. The goal of this study was to examine the applicability of the New Ecological Paradigm (NEP) scale among young learners in India. Differences in environmental attitudes based on the NEP was examined between game players and the control group.

Chapter Two Overview

This quasi-experimental study examined the effectiveness of DGBL in producing attitudinal and behavioral changes regarding environmental sustainability and about learning experiences from a game. One group of undergraduate students in an educational technology course played EnerCities, an ESE game. Another group played a Science game that was not connected to ESE. All other conditions were similar for both the groups. An embedded mixed methods study approach was used where the qualitative methodology was placed or nested within the framework of a quantitative methodology (Caracelli & Greene, 1997; Creswell & Plano Clark, 2018).

The Attitudinal Learning Instrument (ALI) was administered to collect quantitative data pertaining to attitudinal and behavioral learning after one week and after five weeks of game play. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to develop a model to measure learning. PLS-SEM allowed the examination of the effect of each survey indicator item. Quantitative findings showed that despite awareness, influence of affective, behavioral and social learning on behavioral intentions of participants who played EnerCities was higher after one week from game play. Also, social learning and influence of social learning on behavioral intentions were higher even after five weeks of game play for experimental group participants. Thematic analysis of qualitative data helped interpret why and how attitudinal changes were produced by the game. Moreover, interviews that were conducted after five weeks clearly indicated that participants remembered their learning and retained their pro-environmental behaviors. They recalled game features that emotionally engaged them and features that challenged them to perform certain behaviors and features that helped gain new knowledge. A list of such game features were created and merged with a previous list (Janakiraman et al., 2018). This could be used by designers of attitudinal learning games. Future research could apply the measurement model created in this study to measure long-term retention of attitudinal and behavioral learning using games and other interventions on socio-scientific topics.

Summary

- Title
    - Effectiveness of Digital Games in Producing Environmentally Friendly Attitudes and Behaviors: A Mixed Methods Study
- Research Question(s)
    - RQ1: Are digital games effective in producing environmentally friendly attitudes and behavioral intentions?
    - RQ2: Were the influence of attitudinal learning gains on behavioral intentions retained over a period of five weeks?
    - RQ3: In what ways did the digital game produce changes in the cognitive, affective, social and behavioral components of attitude?
- Methods
    - Embedded mixed methods research design

  Data Collection Methods
    - Quantitative: Quasi-experimental using Attitudinal Learning Instrument (ALI) survey instrument
    - Qualitative: Interviews

  Data Analysis Methods
    - Quantitative: Partial Least Squares Structural Equation Modeling (PLS-SEM)
    - Qualitative: Thematic analysis using a deductive approach
- Publication Status
    - Published in *Computers and Education.*

Chapter Three Overview

The goal of environmental sustainability education should be to create eco-awareness and produce pro-environmental behaviors. Several studies conducted in different contexts on collaborative and individual learning from games showed that knowledge acquisition was greater in collaborative learning. The aim of this study that was conducted in an Indian high school was to examine the effectiveness of DGBL in attitudinal learning when played individually and when played in teams. The game used in this study was again EnerCities that was purposefully designed

to provide cognitive knowledge, engage learners emotionally by showing the consequences of harmful behaviors and encourage correct behaviors. Surveys based on the Theory of Planned Behavior (TPB) and the Attitudinal Learning Instrument (ALI) were used to collect quantitative data that was analyzed using Partial Least Squares – Structural Equation Modelling (PLS-SEM) that explained the effect of each indicator item in the survey. Based on the ALI, it was found that there were no differences between the two groups, showing that irrespective of how the game was played, the attitudinal learning from the game was impactful in influencing pro-environmental behavioral intentions. Also, based on the TPB, irrespective of how EnerCities was played, collaboratively or individually, the attitude towards behavior (ATB), social pressure (SOP) and perceived behavioral control (PBC) had similar influences on pro-environmental behavioral intentions (INT). In this study PBC moderated SOP and ATB producing statistically significant influences on behavioral intentions for all game players combined (Ajzen, 2019) that was supported by qualitative data as well. This moderation effect has not been tested in prior studies.

Next, differences between students who played the game and those who did not play any game were examined. In India, traditional instructional methods are used to teach environmental studies (EVS) and all the participants had studied EVS from grade 3 to 5 as dedicated subjects. Later in higher grades, EVS was integrated into other subjects, hence prior knowledge levels were similar for both the groups. This study found that game players showed significantly higher attitudinal learning that influenced pro-environmental behavioral intentions.

Both collaborative and individual game players were interviewed. This showed that the learning strategies used by individual players and collaborative players were different although their attitudinal learning was the same. For example, while collaboration helped players share complex tasks and take decisions quickly, individual players were often frustrated when stuck with a problem. All players mentioned how EnerCities affected them emotionally and how it helped encourage new behaviors or reinforced existing behaviors.

Summary

- Title
    - Exploring the Effectiveness of Digital Games in Producing Pro-Environmental Behaviors when Played Collaboratively and Individually: A Mixed Methods Study in India

- Research Question
    - RQ1: (a) Are digital games more effective in influencing pro-environmental behaviors when played collaboratively or when played individually as explained by the TPB Model?

      (b) Are digital games more effective in influencing pro-environmental behaviors compared to traditional EVS educational methods as explained by the TPB model?
    - RQ2: Are digital games more effective in producing attitudinal learning when played collaboratively or when played individually as measured using the ALI?
    - RQ3: What were students' perceptions of their game play experience?
- Theoretical Framework
    - Theory of planned behavior (Ajzen, 2019)
- Methods
    - Embedded Mixed Methods research design

  Data collection methods

    - Quantitative: Survey based on TPB and ALI
    - Qualitative: Interviews, observations and game score cards

  Data analysis methods
    - Quantitative: PLS-SEM
    - Qualitative: A priori codes using a deductive approach
- Publication Status
    - Under review with *TechTrends* special issue – Minor revisions.

Chapter Four Overview

This study was focused on whether high school students were aware of anthropogenic activities that cause environmental degradation related problems. Often people fail to perform pro-environmental behaviors because they believe they cannot make a difference or they focus on short-term benefits. This mixed-methods study conducted among high school students in India, examined differences in pro-environmental attitudes and behaviors between students who played EnerCities, and students who did not play that game, using the New Ecological Paradigm (NEP;

Dunlap et al., 2000) scale. The NEP scale is comprised of 15 statements to measure environmental attitudes and beliefs towards specific environmental issues. It has been used in diverse contexts but not in studying the effectiveness of digital games in India among K-12 students. Game players showed significantly higher environmental attitudes compared to the participants who did not play the game. This comparison was made considering the unidimensional and multidimensional properties of the NEP scale and similar results were obtained. Thematic analysis with an inductive approach identified from the interview data, how EnerCities changed participants' environmental attitudes and behaviors. Specific quotes related to participant opinions with respect to the NEP items were listed. This study finds implications for implementing games and using the NEP to examine environmental attitudes of high school students in India.

Summary

- Title
    - Influence of Digital Games on Pro-environmental Attitudes and Behaviors: A Mixed Methods Study in India using the New Ecological Paradigm Scale
- Research Question
    - Were there any differences in the environmental attitudes between students who played the EVS game and students who did not play the game based on the New Ecological Paradigm scale?
    - What were the perceptions of participants who played the game regarding their environmental attitudes and behaviors?

- Methods
    - Convergent mixed methods study

  Data Collection
    - Quantitative: New Ecological Paradigm (NEP) scale
    - Qualitative: Interviews

  Data Analysis Methods
    - Quantitative: One-way ANOVA and MANOVA (multivariate analysis)
    - Qualitative: Thematic analysis using an inductive approach

- Publication Status
    - Submitted to Journal of Education for Sustainable Development on July 11, 2020

All the above three studies from my dissertation explored the effectiveness of DGBL in environmental sustainability education. They helped me conclude that DGBL is an effective pedagogical tool in attitudinal instruction where the goal is to influence all the three components of attitude: cognitive, affective and behavioral (Kamradt & Kamradt, 1999; Simonson, 1979) and social learning, where interaction with others influences attitudes (Watson et al., 2018). The following three chapters are articles written based on the three studies. The last chapter provides the discussion and conclusion covering all the three studies.

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CHAPTER 2: EXPLORING THE EFFECTIVENESS OF DIGITAL GAMES IN PRODUCING ATTITUDINAL LEARNING IN ENVIRONMENTAL SUSTAINABILITY EDUCATION: A MIXED METHODS STUDY

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Abstract

Awareness of environmental sustainability issues alone is not enough. Environmental Sustainability Education (ESE) should produce changes in attitude and encourage lifelong behaviors. However, behavioral changes are curtailed by constraints and negative perceptions, necessitating the use of persuasive pedagogical tools in ESE. Digital game-based learning (DGBL) environments provide cognitive knowledge, besides emotionally engaging learners by letting them test new behaviors and seeing the consequences instantly. This study examined the effectiveness of DGBL in producing attitudinal and behavioral changes regarding environmental sustainability and about learning experiences from a game, through a mixed methods study. One group of undergraduate students in an educational technology course played EnerCities, an ESE game. Another group played a Science game that was not connected to ESE. The Attitudinal Learning Instrument was administered to collect quantitative data pertaining to attitudinal and behavioral learning after one week and after five weeks of game play. Partial Least Squares Structural

Equation Modeling (PLS-SEM) was used to develop a model to measure learning. PLS-SEM helps analyze relationships simultaneously in complex models. Quantitative data analysis using PLS-SEM showed that EnerCities was effective in producing attitudinal and behavioral changes that were retained until one week of game play. Thematic analysis of qualitative data, collected through interviews after five weeks of game play, helped interpret why and how attitudinal changes were produced by the game. This provided insights into what game features facilitated cognitive, affective, behavioral and social learning and learning retention, that could be used in future game design. Future research could apply the measurement model to measure long-term retention of attitudinal and behavioral learning using games and other interventions on socio-scientific topics.

Keywords: digital games, improving classroom teaching, lifelong learning, teaching/learning strategies, informal learning

Introduction

A growing world population and limited natural resources, makes it imperative to learn to live together sustainably because what we do today will impact the lives of people and the planet in the future in terms of rising temperatures, climate change and other calamities (Arora, 2018; Brinkman, 2020; Harker-Schuch et al., 2020; Osiobe, 2020; UNESCO, n.d). Environmental Sustainability Education (ESE) is a tool to ensure that young learners learn about sustainability issues and develop environmentally friendly attitudes and behaviors (UNESCO, n.d.). ESE is "learning to value sustainable relations between people (social relations); between people and the rest of the bio-physical world (environmental relations); and between the elements of the non-human world (ecological relations)" (Huckle, 2012, p. 35). However, creating awareness and intentions alone do not produce environmentally friendly behaviors (Arbuthnott, 2009) because behaviors are curtailed by constraints, barriers and negative perceptions (Tucker, 1999). ESE should foster a sense of personal responsibility that persuades learners to find and execute innovative solutions when encountering environmental problems (Griset, 2010). Since environmentally friendly practices have immediate and long-term impacts on environmental sustainability, ESE should produce changes in attitude and encourage lifelong behaviors. This necessitates persuasive pedagogical tools in ESE (Sinatra, et al., 2012), such as digital game-based learning (DGBL) environments.

DGBL provides cognitive knowledge and also emotionally engages learners in environmental problems, allowing them to test new behaviors, and understand the consequences (Knol & De Vries, 2011). Games increase emotional engagement, memory consolidation and learning retention, showed Ninaus et al. (2019) in a study, using facial emotion detection and a machine learning approach. DGBL is perceived by both genders as useful in environmental education and easy to use (Cheng et al., 2013). Moreover, digital games are popular with young students, and it is wise to leverage the intrinsic motivation that games provide to make learning fun and enjoyable (Chen et al., 2019; Gee, 2007; Prensky, 2003; Troussas et al., 2019).

Digital games are considered meaningful teaching tools by various subject teachers (Acquah & Katz, 2020; Chen et al., 2015; Ferguson et al., 2020; Huizenga et al., 2017; Watson et al., 2011). However, there are not many studies that consider socio-scientific topics and attitude change, and the need for long-term retention of learning from games (Cheng & Annetta, 2012; Harker-Schuch et al. 2020). In this study a mixed methods approach was applied to examine whether EnerCities, an educational game designed for ESE, was effective in producing environmentally friendly attitudes and behavioral intentions, and how the digital game produced attitudinal learning and learning retention.

This study was conducted among undergraduate students enrolled in an educational technology course. One of the topics was DGBL and students were required to play a game to experience the DGBL environment. One group of students played EnerCities, role playing as city planners to create a sustainable city by balancing environmental health, happiness of citizens, resource depletion and economic hurdles. Another group of students role played as a surgeon in an equally challenging game and performed surgery on a person who had fractured his arm bone. Students had to plan the surgery, pick appropriate tools and within a fixed time prevent the patient from dying. Both groups were instructed to play the game 2-3 times. The quantitative part of the study was quasi-experimental and Structural Equation Modeling (SEM) was used to analyze and compare the two groups. A thematic analysis approach was used to analyze the qualitative data to understand the learning experience from EnerCities and to create a list of game features that influences attitudinal learning. The study results provide implications for using DGBL successfully in attitudinal learning regarding environmental sustainability. The methodology could be extended to studies involving digital games on other socio-scientific topics as well.

Literature Review

For learners to develop lasting behaviors to ensure a sustainable future, understanding the dynamics of the world they inhabit is critical (Fabricatore & López, 2012), to gain situated understandings (Gee, 2008). Games in ESE can encourage learners to engage emotionally and make important decisions in a safe environment, besides enabling learners to learn collectively with others (Janakiraman et al., 2018).

Attitude and Attitudinal Learning

According to Gagne et al. (1992), an attitude is the psychological evaluation a person has regarding an object, person, or event. The three constituent components of attitude are: cognitive component based on information, knowledge and thoughts; affective component based on emotions or feeling, and the behavioral component, the pre-disposition to act (Kamradt & Kamradt, 1999; Simonson, 1979). Sustainability related attitudes are "an individual's positions with regard to sustainable development" and those "subjective opinions developed with respect to sustainable development may shape an individual's behavior" (Tsai, 2018, p.16).

Attitudinal instruction tries to influence learner's existing attitudes positively or negatively resulting in attitudinal learning (Watson et al., 2018a). Often, attitudinal learning do not produce long-term behavioral changes because learned environmental attitudes are forgotten and inconvenient to practice (Arbuthnott, 2009; Hungerford & Volk, 1990; Tucker, 1999). Hence, ESE should create feelings of empathy and encourage learners to perform environmentally friendly behaviors (Yang et al., 2012). According to Kamradt and Kamradt (1999), this can be achieved, by making learners perform an action that is slightly different from their existing attitude and slightly matching the target attitude. Instruction focusing on attitudinal learning might promote positive attitudes towards sustainability and resulting behavior such as impacting learner perceptions towards recycling, which is different from instruction focused on learner beliefs, motivation or self-efficacy in learning about climate change (Watson et al., 2018a). In addition, social learning is another core aspect of attitude change, where interaction with others influences attitudes (Watson et al., 2018a).

DGBL and Attitudinal Learning

The following sections will discuss how DGBL targets all components of attitudinal learning intentionally to make ESE persuasive.

Cognitive learning. DGBL differs from conventional teaching models, going beyond providing cognitive knowledge (Chen et al., 2019; Hungerford & Volk, 1990) by offering two modes of interaction: learning for playing and learning from playing (Hong et al., 2013). Either way DGBL can be used to provide cognitive knowledge (Bell, 2016) because games increase players' understanding of sustainability issues by providing immersive environments (Katsaliaki & Mustafee, 2015). Also, cognition and metacognition can be enhanced by appropriate prompting in sustainability related games (Zumbach et al., 2020).

Games serve as complex systems, providing problem-solving exercises that allows learners to think and learn about the interrelationship between events (Brinkmann, 2020; Staniškis & Katiliūtė, 2016; Nordby et al., 2016). The real-world scenarios in DGBL environments create complex, situated and meaningful contexts, enabling learners to examine the results in real-time, not possible in real life (Liarakou et al., 2011). Fabricatore & López (2012) conducted an exploratory study about games and concluded that games could encourage complex systems thinking and provide a systemic understanding of sustainability that forms the basis of sustainability education.

Behavioral learning. The negative impact of wrong decisions and harmful behaviors on the environment are not known immediately, because consequences get revealed only when it becomes disastrous (Arbuthnott, 2009). However, game players can try alternative approaches, test their ideas, and learn from mistakes all within a safe zone (Knol & De Vries, 2011). Games are successful in providing awareness of balanced ecosystems (Tan & Biswas, 2007), and in changing behaviors regarding environmental protection and recycling by revealing consequences immediately (Wu & Huang, 2015). Referring to a 3D interactive digital game, Harker-Schuch et al. (2020, p.13) stated:

> Visualizing climate change helps learners interpret complex information in a meaningful and comprehendible way; visually and dynamically representing processes and mechanisms that may be impossible to explore in real life.

Thus, games provide meaningful practice that could be transferred to real life (Butler, 1988) by providing real-world scenarios that produce self-awareness of eco-friendly practices (Yang et al., 2012).

Affective learning. Games can produce affective learning when designed to create empathy through simulated scenarios because they are emotionally engaging (Ninaus et al., 2019). In a "cyber-pet nurturing game," players were emotionally engaged when trying to ensure their cyber-pet's comfort while keeping energy consumption low (Yang et al., 2012). Similarly, Tan and Biswas (2007) found that learners were emotionally involved with a "building and sustaining a fish tank" game and tried to keep the virtual fishes alive even after finishing their challenge.

Friedlander et al. (2011) emphasized that optimal learning occurred when repetition, planned redundancies, multiple modalities, rewards, active engagement, and visualizations were present in instruction, based on the biological basis of learning and memory formation in humans. More than traditional forms of instruction, games possess these features, making them effective pedagogical tools. The discovery learning environment in games (Tan & Biswas, 2007) enable interaction with game elements and other decision makers, to understand the consequences of actions safely (Gee, 2007; Knol & De Vries, 2011; Wu & Huang, 2015).

Studies on DGBL for attitudinal learning have focused on cognitive learning in the form of pre- and post-test formats and only discuss behavioral learning and affective learning within the game environment, using observations during the study. These studies do not show evidence of participants continuing their behaviors in real-life and do not include perspectives from participants about their learning experiences. Although games are emerging as powerful learning tools, they are not used widely in instruction involving socio-scientific topics and attitude change, necessitating more evidence.

Current Study

The goal of this study was to examine whether a game designed for ESE was effective in influencing environmentally friendly attitudes and behaviors, where participants may have similar awareness levels and experiences related to environmental issues. One group of participants was assigned an ESE game and compared with another group that served as the control, where participants did not receive the experimental treatment (ESE game). Other than not playing the game, the control group closely resembled the treatment group. At the university where this study

was conducted, environmental sustainability was taken seriously and there were plenty of opportunities for students to display environmentally friendly behaviors. All waste disposal bins were marked to collect disposable waste and recyclable waste like plastics and bottles. Environmental sustainability was a theme in a year-long series of events, colloquia and seminars. University buildings and commuting buses were also decorated with banners based on this theme. Hence the awareness creating opportunities regarding environmental sustainability was significant.

All participants were exposed to the same environment in the university and none were enrolled in any environmental sustainability course. This mixed methods study was conducted to explore whether games produced attitudinal learning that influenced behavioral intentions, whether the learning was retained over a five-week period, and how the game produced the learning. While this is not equivalent to a longitudinal study, the retention of attitudes and behavioral intentions over five weeks is important. If a behavior is learned and performed in stable contexts and is performed more often, then it is more likely to become automatic or habitual, that could produce a long-term behavioral change (Aarts & Dijksterhuis, 2000; Ouellette & Wood, 1998). DGBL offers such a stable environment because it allows the performance and testing of behaviors, helps visualize the consequences, allows taking alternate actions, and leads to new learning.

Specifically, our research questions were:

RQ1: Are digital games effective in producing environmentally friendly attitudes and behavioral intentions?

RQ2: Were the influence of attitudinal learning gains on behavioral intentions retained over a period of five weeks?

RQ3: In what ways did the digital game produce changes in the cognitive, affective, behavioral and social components of attitudinal learning?

Methods

As recommended in design literature (Kamradt & Kamradt 1999; Simonson, 1979) the three attitudinal learning components (cognitive, affective and behavioral) were examined in this study in addition to considering the learning that occurs through the social interaction of learners (Dole & Sinatra 1998).

Research Design

An Embedded Mixed Methods research design (Figure.1) was employed with the qualitative methodology placed or nested within the framework of a quantitative methodology (Greene & Caracelli, 1997; Creswell & Plano Clark, 2018). According to Plano Clark et al. (2013) embedded designs offer unequal priority to the quantitative and qualitative components when addressing the research questions. RQ1 and RQ2, the primary questions were answered by the quantitative approach, and RQ2 the secondary question was answered by the qualitative approach that was supplementary and provides in-depth understanding, although data was collected from fewer participants (Plano Clark et al., 2013).

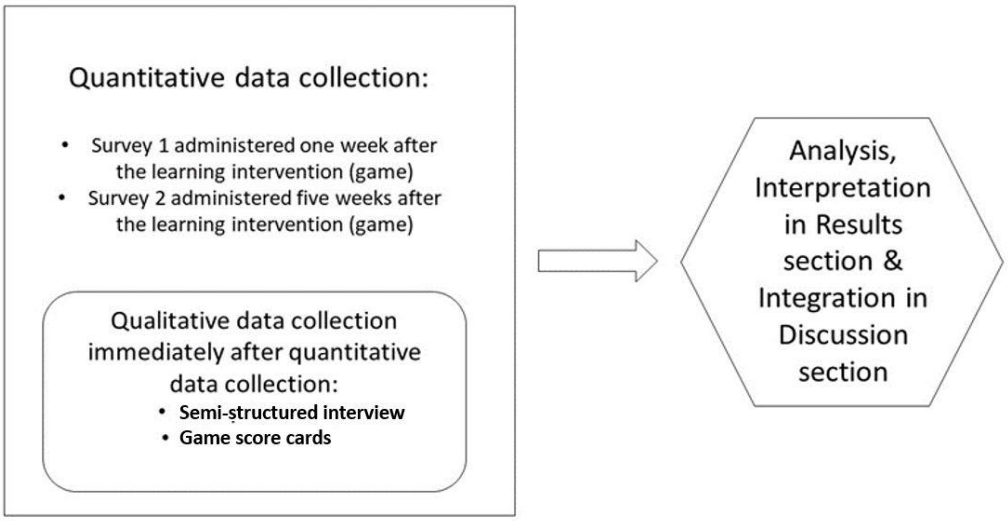

Figure 1: Embedded mixed methods research design

Participants

The participants belonged to two sections of students enrolled in an undergraduate educational technology course for pre-service teachers in a large mid-western university in the United States. They were comprised of freshman, sophomore and juniors aged 18 to 21 years who were studying different majors but pursuing teaching licenses. The quantitative part of this embedded mixed methods study was quasi-experimental where the participants were not randomly assigned to the treatment (Price et al., 2015) that is the ESE game intervention. To examine the differences that a game designed for ESE could produce in learners' attitudes, one section of students played EnerCities, the intervention game. The control group section played another equally challenging Arm Surgery game. In experimental studies, control groups do not receive the same treatment as the experimental group, or they do not receive any intervention at all. In this study however, another game not related to environmental sustainability was assigned to the control group to establish similar conditions between the two groups for comparison purposes. Since the study was conducted over five weeks, providing game environments to all the students enrolled in the course prevented any bias in participant responses to the surveys. The two games also served the objectives of the educational technology course as demonstrations of DGBL as an important tool in educational technology, that the participants (preservice teachers) might consider using in their future teaching careers.

As discussed above, all participants were exposed to the same opportunities related to environmental sustainability and none of them were enrolled in a course related to environmental sustainability. Hence, the prior knowledge of both groups was similar. This helped examine the attitudinal learning of the experimental group from the ESE game, by comparing with the control group. While exposure to an intervention is likely to produce positive learning outcomes, this study examines attitudinal learning, including behavioral learning over time, rather than just the regurgitation of cognitive facts immediately following introduction of the intervention. Therefore, a control group was utilized to evaluate the degree to which the game was able to produce over time attitudinal learning in general and behavioral learning specifically. Although the two sections represented non-equivalent groups by not being randomly assigned into the two treatments, selecting two sections of the same course that comprise a similar mix of students helped increase the internal validity of the study (Price et al., 2015). Moreover, all participants may have similar

awareness levels and experiences owing to the popularity of environmental issues. To reduce the possibility of the qualitative data collection introducing a bias, interviews were conducted after the intervention was complete and after all the quantitative data was collected (Creswell & Plano Clark, 2018). Participation in the surveys and interviews was entirely voluntary.

Access to the games and links to the surveys were made available on the course LMS of the respective sections along with instructions. Answering the surveys was not compulsory, but playing the game was a course requirement. Only survey data of students who played the game and answered both the surveys was included. The experimental group was comprised of 52 students and the control group 42 students. Neither game covered course material, and both groups were given the same inputs about DGBL and its applications in education. Hence there was no loss of learning for the control group. IRB clearance was obtained before data collection started.

Context

EnerCities is a Serious Educational Game (SEG) that uses video gaming technology to design engaging learning activities for learners, to improve their learning experience and learning outcomes (Barclay & Bowers, 2020). It is a 3D game that teaches about renewable and non-renewable sources of energy, created by Qeam, an EnerCities consortium member with the support of the University of Twente (Knol & DeVries, 2010; 2011). In the game, students were required to create a sustainable city by engaging in activities normally not performed in their daily lives. They role played as city planners in a real-world scenario, making decisions that are environmentally friendly, sustainable, cost effective, and kept the citizens of the virtual city happy.

The game depended on actions executed by the players who had to monitor indicators to see their progress. All icons and indicators incorporated pop-up boxes that contained additional information. For example, clicking on the solar farm icon provided the purposes, applications, space required, and cost of establishing a solar farm. This facilitated cognitive learning. Happiness of the virtual citizens in the city was indicated by smiley faces and the green cover by a tree icon. The smiley face becoming sad or the green color tree icon becoming red indicated urgency and produced an emotional connect that facilitated affective learning. By immersing themselves in a real-life complex situation, players learned about how wrong decisions would lead to problems like environmental degradation, citizens' reduced happiness, economic hurdles, and the depletion of fossil fuels. For example, when the player constructed a stadium or marketplace by clearing

forests, indicators for energy, funds, fuel, and greenery showed a negative reaction. By testing behaviors and seeing immediate consequences, behavioral learning was facilitated. Social learning in games can be promoted when players discuss their scores, share strategies to increase scores, and while sharing new knowledge they found in a game. The screenshots from the game (Figure 2 and Figure 3) show two stages of building a sustainable city within EnerCities.

The Arm Surgery game played by the control group was equally challenging and was selected because it incorporated similar game mechanics to EnerCities. In the game the player had to perform a surgery using the correct instruments. Information boxes provided detailed explanations about the need for surgery and descriptions of surgical instruments, providing knowledge. The surgery had to be completed within a particular time period indicated by monitors that showed the time and vital parameters of the patient. The player had to keep an eye on these to perform the surgery before the patient expired, that provided an emotional connect. This game was skills based and time bound. From the game, players learned to pay attention and accomplish correct actions sequentially, to be successful.

The surveys featured questions pertaining to participants' attitudes and behaviors and did not refer to the game or behaviors within the game. This helped ascertain the effectiveness of the game in promoting attitudinal learning and behavioral intentions regarding environmental sustainability.

Figure 2. Screenshot 1

Figure 3. Screenshot 2

Data Collection and Analysis

This involved two-phases: quantitative data was collected first, and qualitative data collected next (Figure 1). Analysis of the quantitative and qualitative databases occurred separately to address the different research questions and were integrated later (Plano Clark et al., 2013).

Quantitative phase

DGBL as an instructional intervention was introduced to both the experimental and control groups during week 10 of their educational technology course. The respective games for the two groups were made available on the course management system. Designed as a repeated measures type of study, a survey with demographics-related questions and items from the Attitude Learning Instrument (ALI) was administered (Watson et al., 2018a) after one week (survey 1) and after five weeks (survey 2) of game play. Collecting the responses after one week and not earlier helped examine whether learning from the game could be retained until a week. The survey administered after five weeks helped examine attitudinal learning retention for a longer period. The same steps were followed for the control group. For analysis, only responses (survey data) provided by students who played the assigned game, and also answered both survey 1 and survey 2 were included. The experimental group was comprised of 52 students and the control group 42 students.

The ALI addresses the need for a self-reflection instrument that can measure students' assessment of the degree to which they perceive changes in their attitudes (Watson & Kim, 2016; Watson et al., 2018a; Watson et al., 2018b). ALI provides a holistic assessment of attitudinal learning by encompassing cognitive, affective and behavioral components of the traditional attitude model along with social-oriented learning. This enables the evaluation of instructional outcomes, and their relation to learner attitudes. ALI comprises of 14 items measured using a 5-point scale where learners rate the degree of agreement with a statement (1-'strongly disagree' to 5 -'strongly agree'). Learner perception of attitudinal learning are represented by: cognitive (3 items), affective (3 items), behavioral (4 items), and social learning (4 items). See Appendix A for a list of the ALI survey items. The last 4 items measured behavioral intentions.

Partial Least Squares-Structural Equation Modelling (PLS-SEM) was used to analyze the data and test the hypotheses. This approach considers the relation between the theoretical conceptualization of the construct (cognitive, affective, behavioral and social learning, and

behavioral intention) and its measurement validation.

PLS-SEM method of analysis allowed the estimation of the parameters of a complex model with many constructs, indicator variables and structural paths without making any distributional assumptions on the data. The causal-predictive approach of PLS-SEM enabled the prediction of behavioral intentions using a statistical model to provide causal explanations (Sarstedt et al., 2017). This improved the study because each construct had multiple indicators and consideration of only those indicators that had significant effect on the constructs was possible. Also, differences between the experimental and control groups was examined using the Multi-Group Analysis (MGA) feature in PLS-SEM. MGA helped test if pre-defined data groups had significant differences in their group-specific parameter estimates of outer weights, outer loadings and path coefficients. This is a non-parametric significance test that employed PLS-SEM bootstrapping results. SmartPLS 3.0 software package was used to explore the model and interpret the results (Ringle et al., 2015). Based on the ALI instrument, the proposed structural model (Figure 4) was used to test the hypotheses.

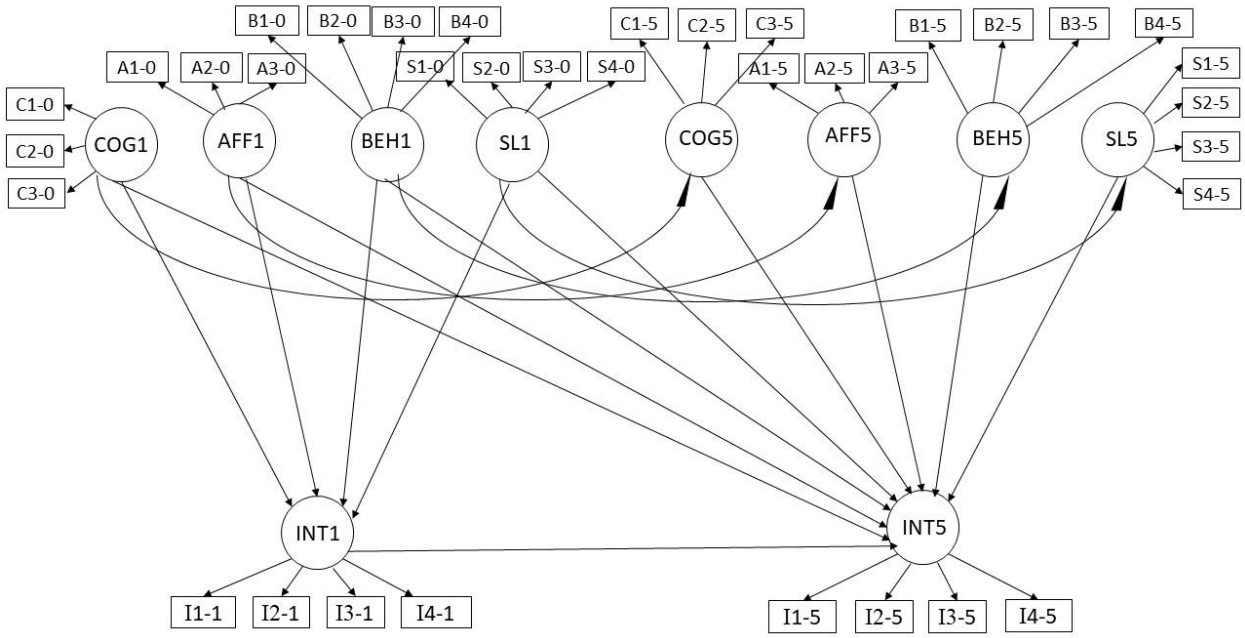

Figure 4. Proposed Structural Model

In Figure 4, C1-0, C2-0, C3-0, A1-0, A2-0, A3-0, B1-0, B2-0, B3-0, B4-0, S1-0, S2-0, S3-0 & S4-0 are indicator survey items (variables) of the learning achieved from the game, that explains the cognitive learning (COG1), affective learning (AFF1), behavioral learning (BEH1) and social learning (SL1) that were retained until one week from game play. I1-1, I2-1, I3-1 & I4-1 are indicator variables that explain behavioral intentions (INT1) one week from game play.

C1-5, C2-5, C3-5, A1-5, A2-5, A3-5, B1-5, B2-5, B3-5, B4-5, S1-5, S2-5, S3-5 & S4-5 are indicator survey items that explain the cognitive learning (COG5), affective learning (AFF5), behavioral learning (BEH5) and social learning (SL5) that were retained until five weeks from game play. I1-5, I2-5, I3-5 & I4-5 are indicator variables that explain behavioral intentions (INT5) five weeks from game play.

It was hypothesized that the intervention game as a pedagogical tool would have a positive effect on attitudinal learning and in influencing behavioral intentions regarding environmental sustainability. Each path in the structural model in Figure 4 represents a hypothesis as shown below.

H1: Influence of affective learning on behavioral intentions after a week is greater for the experimental group.

H2: Influence of affective learning on behavioral intentions after 5 weeks is greater for the experimental group.

H3: Retention of affective learning for 5 weeks is greater for the experimental group.

H4: Influence of affective learning after 5 weeks on behavioral intentions is greater for the experimental group.

H5: Influence of behavioral learning on behavioral intentions after a week is greater for the experimental group.

H6: Influence of behavioral learning on behavioral intentions after 5 weeks is greater for the experimental group.

H7: Retention of behavioral learning for 5 weeks is greater for the experimental group.

H8: Influence of behavioral learning after 5 weeks on the behavioral intentions is greater for the experimental group.

H9: Influence of cognitive learning on the behavioral intentions after a week is greater for the experimental group.

H10: Influence of cognitive learning on the behavioral intentions after 5 weeks is greater for the experimental group.

H11: Retention of cognitive learning for 5 weeks is greater for the experimental group.

H12: Influence of cognitive learning after 5 weeks on the behavioral intentions is greater for the experimental group.

H13: Influence of social learning on the behavioral intentions after a week is greater for the experimental group.

H14: Influence of social learning on the behavioral intentions after 5 weeks is greater for the experimental group.

H15: Retention of social learning for 5 weeks is greater for the experimental group.

H16: Influence of social learning on the behavioral intentions after 5 weeks is greater for the experimental group.

H17: Retention of behavioral intentions for 5 weeks is greater for experimental group.

To start the analysis, the sample size was assessed to see if it would provide "sufficient statistical accuracy to detect effects of interest," by relying on a power analyses (Benitez et al., 2019, p. 7) using G*Power 3.1.9.4 (Hair et al., 2016). The sample size of 94 exceeded the required minimum sample size of 81. The overall model fit measured using the standardized root mean square residual (SRMR) determined that "the empirical data stems from a world that functions as theorized by the model" (Benitez et al., 2019, p. 12). The SRMR was 0.07 (less than the recommended threshold value of 0.08).

PLS-SEM was executed using bootstrap taking 3000 subsamples. On assessing the structural model, the indicator loadings were found to be higher than the recommended value of 0.708 showing that the construct explains more than 50% of the indicator's variance providing acceptable item reliability (Benitez et al., 2019). Internal consistency reliability was indicated by composite reliability values, Cronbach's alpha and the rho values. All indicators showed reliability values between 0.70 and 0.90 satisfying the requirement. Convergent validity was assessed from average variance extracted (AVE) values that explains the extent of the convergence of the construct measures. They were higher than the recommended value of 0.50. Hence, the loadings, internal composite reliability and construct validity were established for our measurement model (See Appendix B & C).

Discriminant validity or the extent to which a construct is empirically distinct from the other constructs in the structural model was given by the Fornell-Larcker criterion (Appendix D). Also, there were no multicollinearity issues. See Appendix E for correlation matrices for the structural model constructs for both groups. The above analysis showed that the proposed model fits the data and hence ready to test the hypotheses and derive the results.

Qualitative phase

Five weeks after participants played the game, and after quantitative data collection was completed, one of the researchers interviewed participants from the experimental group. Since the goal of the qualitative phase was to answer RQ3 and understand why and how EnerCities influenced learning experiences, for the semi-structured interviews, only individuals in the treatment group were included because "investigators seek to understand why the experiment treatment worked or did not work" (Creswell & Clark, 2018, p.119). The last question in the survey requested interview participation. The survey also mentioned that a $10 gift card reward would be given in recognition of participants' services in answering all the questions during the interview, regardless of their responses. Participation was voluntary and nine students agreed to be interviewed. The interviews helped gain in-depth knowledge into their learning experiences from the EnerCities game although data was collected from fewer participants (Plano Clark et al., 2013).

The interview questions included: participants' perceptions of the EnerCities game, and how game features helped in the learning experience. See Appendix F for the semi-structured interview questions. The 20-30 minutes long interviews (per participant) were audio-recorded, transcribed verbatim, and stored on password-protected computers. Game score cards generated at the end of the game were used to assess total time spent on playing the game, and how well game goals of balancing the happiness levels of the citizens, environmental health, the economy, and natural resources were achieved. These were analyzed to ascertain the engagement, and performance of the interviewees to validate their opinions about the game.

Interview data was analyzed by thematic analysis using a deductive approach that involved analyzing data based on preconceived themes and guided by research questions, existing knowledge and literature (Braun & Clarke, 2006). First, the interview data was read, reviewed and

coded, followed by grouping into categories based on patterns. The categories were combined and defined based on themes (Merriam & Tisdell, 2016): cognitive, affective, behavioral and social learning, and game features. While discussing their learning, participants mentioned their thinking processes and game features that helped them learn new knowledge (cognitive learning, e.g. virtual agent); how game features affected them emotionally and made them feel the urgency to act (affective learning, e.g. happy and sad smiley faces), and about actions they performed and instant feedback (behavioral learning, e.g. feedback from monitors). In addition, "real-world perspectives" emerged as a theme that influenced all the components of attitude. This helped answer how EnerCities produced changes in the cognitive, affective, behavioral and social learning. See Appendix G for the coding scheme.

The in-person semi-structured interviews (Merriam & Tisdell, 2016) provided a rich source of qualitative data and along with the quantitative data, ensured methods triangulation, (Denzin, 1970). Participants' own words are quoted in this manuscript to serve as persuasive descriptions and to enable readers to connect with participant opinions (Erickson, 2012). Examining multiple sources of data from surveys, interviews, and score cards helped establish data triangulation (Denzin, 2012; Lincoln & Guba, 1985; Miles & Huberman, 1994). Several rounds of discussion and feedback among research team members, during the research design, data collection and analysis stages added research rigor (Denzin, 1978; Patton, 2015), and established investigator triangulation (Denzin, 1978).

Results

The results were interpreted to examine if the EnerCities game was effective in changing energy-related attitudes and behaviors, when there was no other intentional instruction devoted to environmental sustainability.

Quantitative Results

Since the measurement model assessment was satisfactory, the PLS-SEM results were evaluated. R^2 values provided the explanatory power of the structural model and since this is an exploratory study (Benitz et al., 2019), the R^2 values (Appendix H) show moderate to substantial

power. The predictive accuracy of the PLS path model is given by the Q^2 values (Shmueli et al. 2016), that are greater than zero indicating predictive relevance of the construct indicators.

Multi-group Analysis (MGA) was executed to compare the influences of attitudinal learning on behavioral intentions between the experimental and control groups. The structural model was examined for significant differences in path coefficients of the hypothesized relationships in the results report (Ringle, Wende, & Becker, 2015) to test hypotheses H1 to H17. See Appendix I for path coefficients.

To examine whether there were significant differences between the path coefficients for the experimental and control group, the PLS-MGA Parametric test results were consulted (See Appendix J). An analysis of path coefficients and significance levels indicated that some of the hypotheses were supported by the data. The following results answer RQ1: Are digital games effective in producing environmentally friendly attitudes and behavioral intentions?

There were significant differences between the experimental and control groups in the following relations:

- H1: Influence of affective learning on behavioral intentions after a week ($p < 0.05$)
- H5: Influence of behavioral learning on behavioral intentions after a week ($p < 0.05$)
- H13: Influence of social learning on behavioral intentions after a week ($p < 0.01$)

The results show that the influence of affective, behavioral and social learning on environment related behavioral intentions for those who played the EnerCities game was significantly higher than those who played the control game after one week of game play. However, there was no significant difference in the influence of cognitive learning on behavioral intentions between the two groups.

Considering RQ2: Were the influence of attitudinal learning gains from games, on behavioral intentions retained over a period of five weeks?

There were significant differences between the experimental and control groups in the following relations concerning retention of learning for five weeks:

- H14: Influence of social learning on behavioral intentions after five weeks ($p < 0.05$)
- H15: Retention of social learning for five weeks ($p < 0.05$)

Social learning and the influence of social learning on behavioral intentions was significantly higher for participants who played EnerCities even after five weeks. This showed that social learning continued to influence behaviors and they were sharing their knowledge about

environmental sustainability with others. The influence of cognitive, affective, and behavioral learning on behavioral intentions after five weeks were not significantly higher for participants who played EnerCities.

Qualitative Results

This section describes the perceptions of the nine participants (experimental group) who were interviewed five weeks after they played the game. The findings answer RQ3: In what ways did the digital game produce changes in the cognitive, affective, behavioral and social components of attitudinal learning? In addition, the findings support the quantitative findings as well.

The game

Irrespective of how many times they played the game (2-5 trials), whether they had played a similar game before, or whether they liked playing digital games, most interviewees expressed positive experiences with the game. Playing the game multiple times allowed players to strategize their decisions in developing their cities and examine the effects of behavioral decisions. Although they preferred more instructions, one participant believed that the discovery form of learning made the game more exciting. Another participant mentioned the "self-instruction" in the game. He said, "… it was telling you kind of what you need to do but you needed to figure it out by yourself." One participant wanted more interconnected aspects within the game. He said, "I wish it was a little more in-depth…have different elements in the game that affect each other…that would have a greater effect in real life." Other participants opined that they liked the structure of the game because it showed how a complex system worked, while also being flexible in allowing various choices in placing buildings, industries, and parks in the city.

Participants were excited about the game, because they wanted to see how the concept could be taught through a game in a "playable format." As players, they took different roles to achieve their targets such as city planner, urban developer, civil engineer etc., which they perceived as exciting. Their thought processes ranged from symmetrical alignment of their constructions to placing power plants away from houses, being critical and creative at the same time. Overall, they defined the game as exciting, challenging and a new learning experience.

Cognitive learning

Two of the nine participants said that the game did not teach them anything new and that, "it was just a neat way to visualize it." Although they were "eco aware" already, and their knowledge was "fairly good" even before the intervention, the game seemed to have made them ponder more about the environment. A participant said, "I know a little more of how that will affect residential living versus just having a coal mine somewhere far away versus having a coal mine near where the people live." They appreciated how the game visually presented the view that fossil fuels are limited, would soon deplete and would be unavailable for future generations. A participant said, "it made me aware that we can't always use oil and coal, but we have to think of these new ways whether we like it or not about renewable resources."

The visualizations helped them learn about the high fuel consumption of heavy industries and how that impacted society and the environment. The visual prompts provided in the game further fostered cognition and metacognition. They learned that human behaviors cannot be focused on only satisfying one's own needs but must also understand the harmful impacts on the environment. One participant mentioned:

> After playing the game I would say I was a little bit more aware of what I am doing and what we're doing to the earth…after the game I noticed more news…about all the plastics that are in the oceans and in the environment. So, I guess my awareness level went up after playing the game.

All players believed that the learning was impactful. Although they realized that achieving optimal balance was impossible sometimes, they realized the importance of keeping citizens happy while also protecting the environment. Considering this interconnectedness presented within the game, a player said that it made her think about how things were connected in real life, taking a systems approach to her learning from the game. Players were constantly linking game play experience with their prior beliefs and real-world experiences in developing their cognitive thinking.

Affective learning

All nine interview participants were affectively involved in their decision-making and felt sad when something went wrong in the game, as displayed by the monitors, realizing the urgency

to right a wrong to bring about a balance. They mentioned the feature of the happy and sad faces. They were upset when "the little smiley face turned into a frowny face," that made them realize that their decision was detrimental to the environment. They wanted to make the population in the game happy and took decisions accordingly. Connecting to real life, a player said, "…this is kind of what other cities are doing in real life, how is it affecting the peoples' happiness, how is it affecting the world right now."

Players were encouraged to think of alternate perspectives. In support of coal power plants, a player said:

> …it made me realize that as much as the power plants cause pollution, they are needed, that is why we still have them around...they are cheaper… it gives you more power and more convenience, basically.

They experienced moments of uncertainty because sometimes citizens in the game wanted more shopping malls and other things that may be bad for the environment.

One participant did not agree with the game feature of placing, "a huge power plant next to the water," and said, "that made me think like if you need it next to the water, it is not good for the water or anything around it." He was worried that it would pollute the water "which is not good." The results showed that the game gave players an immersive environment that encouraged critical thinking and taking of alternate perspectives.

Behavioral learning

Discussing his prior beliefs, one student said, "Some behaviors do not hurt the environment as much as others; they also have an impact, but some can be beneficial to us but not absolutely violate nature." This indicated a mixed feeling about the impact of wrong behaviors, a sentiment expressed by three other participants as well. Three interviewees knew about environmentally friendly behaviors prior to playing the game but were not mindful of their actions. For example, a participant mentioned, "Did not do so much I guess on the electricity and water standpoint…I was aware of [them] before the game." Two participants who had worked in locations that prioritized eco-friendly actions were mindful of their behaviors already.

Referring to the monitors in the game, all participants said that they had a tough time balancing the "natural resources" and "general happiness," and they were constantly striving for "greater yields" as a primary goal, keeping an eye on the "money meter," as well. As one noted:

> I liked how it had limitations to what I could do based on my own actions…it made me learn…hey don't do this a second time, but in real life we don't have those, real second opportunity.

This learning is impactful because participants realized that unlike a game, there will be no second chance in real life.

Balance was a theme that appeared many times in the interviews and participants were striving to "balance citizens' happiness and resources" with an "economic mindset." Players learned to maintain an optimum balance between resources and not focus only on people's happiness. A participant said, "…even though the happiness levels kind of going down we can't really build parks because that doesn't really do a lot to the game, so that's kind of… you look at statistics." A student majoring in agriculture went beyond the game and started thinking of incorporating agriculture in the form of vertical farms and roof top farms when developing cities with high-rise buildings, as it appears in the game, to find a balance.

Those who were environmentally conscious continued their behaviors with greater awareness about whether they were doing it correctly. They started performing new actions too, like shutting down the computer when not using it "because even if it is not on, it is still taking up energy being plugged in," a participant said. Two participants who were not mindful of their actions prior to playing the game made a few changes to their behaviors and appreciated the fact that this game reminded them of an "environmentally friendly mindset" and its importance. A participant said, "I did start recycling and started seeing those…news more, about the plastics in the ocean. I did start researching a little bit more." One participant perceived that he did not have control over certain behaviors:

> There are things that I can't really control, like I try not to use as much water, I try not to use as much electricity, I try to recycle when I can, but then there are things that is just out of my control that I can't really affect."

Others who were uncertain learned that even small actions are important in protecting the environment and started performing new behaviors, including reminding roommates to shut off

the lights, recycling more, reducing water and energy consumption and watching news broadcasts linked to the environment and pollution. All players believed that behaviors within the game could transfer to real life and could be retained long term. “These games…do affect people’s behavior when they are playing them,…they affect them after they are done playing them,” said a participant who concluded that “if a realistic approach is taken to designing these games, then they would, “curb peoples’ appetite for fossil fuels.”

Social learning

All participants were attracted to the competitive environment with others and talked about their scores. Seven of them shared game play experiences and their learning with friends and family. Two did not because they believed that their friends and family were already environmentally friendly. One participant said that she shared the game with her friends, and they continued playing to beat each other’s scores for few days.

Although participants did not mention that they would voluntarily seek to educate others about environmentally friendly behaviors, all of them expressed their willingness and confidence to share their learning with others after playing the game “in the context of larger discussions,” and, “if it ever came up” in a conversation.

Real-life perspective

By reflecting over the course of the game, players considered real life consequences with every action in the game. One participant said:

> It made me think about the real world and what needs to go around what areas, so I needed to have a resource for my buildings … and yet have a park for people to go to…. I had an idea that you needed [energy] sources in bigger cities and smaller cities, but I didn’t realize how much it takes to power those things.

They connected the end of fossil fuel supplies in the game, as revealed by the monitor, to real life and realized that humans currently are on a path to having significant challenges when fossil fuels run out. Discussing her learning from the game, one participant said, “it was more of [a] mixture of my personal beliefs and game experiences because growing up on a farm site, you know what affects what.”

The game encouraged players to think critically, connect to prior beliefs, offer alternate perspectives, and connect their actions within the game to the real world. Many participants opined that behaviors within the game reinforced their existing eco-friendly behaviors besides encouraging new ones related to energy use that could become habits. The findings showed how EnerCities produced the learning, answering RQ3. It must be noted that the interviews were conducted after five weeks of game play and that participants' attitudinal learning and behaviors were retained, pointing to the efficacy of games in ESE supporting the findings from RQ1 and RQ2.

Discussion and Implications

The results from the quantitative and qualitative analysis are integrated here to understand and construct "the subjective meanings of experiences" and "to examine the complexity of phenomena as experienced by individuals" (Plano Clark et al., 2013, p. 226).

Huckle (2012) defined ESE as learning to value sustainable social relations, environmental relations and ecological relations and Arbuthnott (2009) argued that ESE must not stop with creating awareness because behavioral changes do not stem from awareness alone. This study showed how digital games go beyond conventional teaching models (Chen et al., 2019) by allowing players to act, see the consequences of their actions, and try alternative strategies, all within the safe zone of the game (Knol & DeVries, 2011).

The survey data did not show significant differences between the two groups regarding cognitive learning. This may be because students are constantly exposed to knowledge about the environment through news, seminars, flyers, and social campaigns about eco-friendliness in the university and in community locations. It is important to observe here that despite the awareness and knowledge, the influence of affective, behavioral and social learning on eco-friendly behavioral intentions was higher for the experimental group after one week. This can be attributed to the game as shown by the interview data that explained their learning experience.

Participants enumerated how visualizations allowed them to see the results of building power plants close to housing units, and how energy consumption increased when they built huge buildings. They learned how people's happiness levels were reduced with increase in construction and pollution, and reduction in green cover. By testing their behaviors and not being afraid of making mistakes, participants learned how human actions could harm the environment. The game

showed the results of wrong actions immediately, unlike real-life, which better illustrated the impacts of their choices and therefore facilitated their behavioral learning (Harker-Schuch et al., 2020; Wu & Huang, 2015). Although they performed actions by taking on the role of city planners, participants were able to transfer that learning to change their daily energy related behaviors like switching off their computers and lights, using less water, recycling, and becoming self-aware of energy conservation practices (Yang et al., 2012; Wu & Huang, 2015).

Prompts in the form of pop-up boxes appeared when icons were clicked providing additional information. This enabled participants to develop critical thinking skills supporting metacognition (Zumbach et al., 2020). After playing, the game players thought about alternate ways to construct buildings and how human-created pollution may affect water bodies if power plants are placed near them. They started imbibing news about the environment taking a wider worldview and moving from a narrow focus on personal needs.

Despite the existence of barriers that curtail behavioral changes (Tucker, 1999), DGBL served as a persuasive pedagogical tool (Sinatra et al., 2012) by demonstrating the complexity that exists in real-world scenarios (Nordby et al., 2016; Fabricatore & López, 2012). Behaviors within the game showed players how one action produces multiple results, some good and some bad. All players mentioned how it was difficult to balance the economy, environment, resources, and the happiness of people. They "learned from playing" (Hong et al., 2013) and understood from the game how one small change can have disastrous consequences. The opportunity afforded by the game to test various strategies and see what worked best proved to facilitate learning. Instead of providing direct instruction, the game provided a discovery learning environment (Tan & Biswas, 2007), allowing players to apply their newfound knowledge and test their behaviors. This helped players take a systems approach to their learning (Liarakou et al., 2011; Staniškis & Katiliūtė, 2016).

Interviewees wanted to make the population in their virtual city happy while trying to be economical and eco-friendly. They were emotionally involved with the sad faces in the happiness monitor, similar to findings from previous studies that used a cyber-pet (Yang et al., 2012) and aquarium fishes (Tan & Biswas, 2007). Those emotions were translated to real life and they believed that in real locations where the environment is degrading, the plight of people will be

similar to the game. Players understood that there will not be a second chance in real life like in the game. This gave them a sense of urgency to do their part. Most of them worried about the depletion of fossil fuels, connected it to real life and wondered aloud what they could do to rectify the problem. This knowledge has been conveyed through various modalities, and players were previously aware of it. But, playing the game and actually experiencing helplessness created a greater impact on their emotions. They kept thinking about the real-life implications of their actions in the game and how it will affect people and the environment, which demonstrates impactful learning (Harker-Schuch et al., 2020; Liarakou et al., 2011; Wu & Huang, 2015).

Only the influence of social learning on behavioral intentions was significantly higher for the experimental group than the control group even after five weeks of game play, according to the survey data. Participants' sharing of scores, and discussing their performance, usually not seen in traditional methods with tests and grades, aligns with "learning for playing" where learners after learning the content are trying to learn a winning strategy (Hong et al., 2013). This shows that the game encouraged players to confidently discuss the game and in turn about their learning with friends and family. Although the interviews were aimed at the learning process and game features, all participants mentioned that EnerCities affected them emotionally and that behaviors within the game could easily transfer to real life behaviors that could be sustained for longer periods of time.

Based on our previous work (Janakiraman et al., 2018), a literature review on DGBL in ESE for attitudinal learning and the thematic analysis in this study as discussed above, a list of game features that influenced cognitive, affective and behavioral learning was created, as shown in Table 1. Interviewees did not mention "motivating," as a game feature specifically. However, some participants played the game multiple times indicating motivation to play (Chen et al., 2019; Troussas et al., 2019). Providing opportunities to repeat actions was recommended by Friedlander et al. (2011) to improve learning. This was also not mentioned in the interviews although players had to repeat similar actions when they were constructing different kinds of buildings. Smiley faces as a game feature to monitor happiness levels did not appear in other studies conducted using other games. For example, in the cyber-pet game (Yang et al., 2012), a feedback system was triggered that gave a text message to indicate the cyber-pet's discomfort. All other features that helped in learning, according to prior studies, appeared in this study as well.

Table 1. Attitudinal learning and game features

Cognitive Learning	Affective Learning	Behavioral Learning
Visualizations	Situated learning	Safe, simulated conditions
Systems thinking	Immersive environments	Active engagement
Prompts	Empathy creation	Live action & practice
Discovery learning	Happiness monitor	Test behaviors
Spirit of inquiry	Realistic scenarios	Motivating
Active engagement		Repetition & rewards

In DGBL, game mechanics or features play an important role in the learning process, and this list could be used to design games to ensure attitudinal learning that could lead to changes in attitudes and behaviors. The table does not include social learning because EnerCities did not have specific features to produce social learning within the game. Also, participants played the game individually. Both the survey and interview data showed that after playing EnerCities, participants talked to others about environmental sustainability and that they were confident to connect to others about the topic. This shows that playing EnerCities itself produced social learning.

At the time of the interview that was conducted after five weeks of game play, all nine participants still remembered what they had learned from the game, the game features, and their emotions while they played, showing the impactful nature of DGBL environments. Moreover, participants had continued to practice environmentally friendly behaviors, and the two participants who were already eco-aware prior to playing the game had increased such behaviors, showing that when behaviors are repeated, they could become habitual (Aarts & Dijksterhuis, 2000; Ouellette & Wood, 1998). This study showed that games can be effective in attitudinal learning and changing behaviors because they allow young learners to test their behaviors and see how harmful behaviors can deteriorate the environment.

Research Contributions and Future Research

This mixed methods study (over five weeks) provided insights into the game's influence on attitudinal learning. By using PLS-SEM the influence of individual indicators in the survey on each type of learning was examined separately and over different points in time. This was

especially useful because it provided greater depth to this exploratory study. The measurement model and the research design can be used in future studies to examine the effectiveness of various educational interventions on attitude change over longer periods of time covering a wide variety of topics like road safety, smoking, health, food habits, and drug abuse. Studies could cover recreational games that incorporate attitudinal change practices as well. Using the ALI, studies can examine attitudinal learning and compare the influence of different types of interventions. The list of game features in Table 1 could be used to design and assess attitudinal learning games. This was an impactful result from this study and needs further research.

Research Limitations

Conducting a pre-survey would have added more insights into the prior attitudes of participants and highlighted the extent of attitudinal learning, however that might have primed all participants about the topic of the study. Also, ALI as an instrument is focused on measuring the impact of attitudinal instruction concerning a variety of topics and is not suitable for a pre-post implementation. Future research could also include a separate survey designed to examine environmental concerns, in addition to the ALI. This limitation was partly overcome by the qualitative data that focused on players of the EnerCities game only. The interviews provided insights into their learning experiences although only nine participants were interviewed (Plano Clark et al., 2013). Participants discussed their prior attitudes, the new learning from playing the game and the retention of learned attitudes and behaviors after five weeks. This, however, does not highlight the attitudes of control group participants.

To control for prior knowledge, this study could have been conducted among students enrolled in an environmental sustainability course to compare effects of the game and traditional methods. Again, the formal environment may have confounded the results and a significant difference between the two groups may not have been detected. Given this possibility we believe that the approach used suited the study goals and can be used by future researchers to test long term attitudinal learning.

Conclusion

Games can be a great alternative to lectures and PowerPoint presentations in changing

attitudes because of the fun, engaging, motivating, challenging, immersive and attractive platform (Chen, et al., 2019; Gee, 2007; Harker-Schuch et al., 2020; Prensky, 2003; Troussas et al., 2019). Games allow players to test their behaviors and see the consequences of harmful behaviors on the environment immediately, facilitating retention of learning and behaviors.

In this mixed methods study, the quantitative data showed that despite awareness, influence of affective, behavioral and social learning on behavioral intentions of participants who played EnerCities was higher until one week from game play. Researchers have stressed the importance of long-term learning from games (Cheng & Annetta, 2012; Harker-Schuch et al., 2020), and the qualitative data in this study showed that attitudinal learning from games to some extent have the potential to be retained longer because of the experiences within the game.

Previous studies used test scores to assess cognitive knowledge gain and observations to assess affective and behavioral learning within the game but did not provide a qualitative assessment of learning experiences from the game and the transfer of learning to real-life. The qualitative phase of this study provided insights into how participants perceived changes in attitudes and behaviors and what features of the game helped them in this process. This helped create a list of game features based on learner experiences and literature, that specifically addresses attitudinal learning that could help instructional designers in designing attitude change games.

Although there are concerns about using digital games in education, this study showed that games could be used for attitudinal learning as they provide knowledge as an experience that is situated in scenarios that help learners develop situated understandings (Gee, 2008).

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Appendix

A: Attitudinal learning Survey (ALI) Survey questions

All items are to be answered on a 5-point scale (1 – 'strongly disagree' to 5 – 'strongly agree')

1. I learned new information about the environment.
2. I am more knowledgeable about environmental sustainability.
3. I picked up new ideas about environmental sustainability.
4. I feel excitement about the topic of environmental sustainability.
5. I feel eager to learn more about environmental sustainability.
6. I feel passionate about the environment.
7. My behaviors related to the environment have changed.
8. I did something new related to environmental sustainability.
9. I made changes to my behavior related to environmental sustainability.
10. I do things differently now with respect to environmental sustainability.
11. I talk to others about environmental sustainability.
12. I educate others about environmental sustainability.
13. I am confident discussing about environmental sustainability with others.
14. I connect with other people regarding environmental sustainability.
15. I intend to switch off my PC when not in use.
16. I intend to reduce my water usage.
17. I expect to recycle waste as much as possible.
18. I intend to switch off the lights when not required.

B: Measurement model assessment

Code	Construct/Indicator (survey items)	Experiment (N=52)		Control (N=42)		Loading
		Mean	SD	Mean	SD	
Cognitive learning (COG1): AVE = 0.854*		3.301	1.036	3.421	.968	
C1-0	I learned new information about the environment.	3.33	1.10	3.55	1.131	0.913
C2-0	I am more knowledgeable about ES.	3.38	1.11	3.40	1.014	0.942
C3-0	I picked up new ideas about ES.	3.19	1.16	3.31	1.000	0.918

Cognitive learning (COG5): AVE = 0.893*		3.833	.939	3.683	.937	
C1-5	I learned new information about the environment.	3.83	1.024	3.60	1.037	0.938
C2-5	I am more knowledgeable about ES	3.81	1.011	3.71	.995	0.952
C3-5	I picked up new ideas about ES	3.87	.971	3.74	.912	0.946
Affective learning (AFF1): AVE = 0.573*		3.673	.703	3.357	.915	
A1-0	I feel excitement about the topic of ES	3.37	.971	3.57	1.151	0.728
A2-0	I feel eager to learn more about ES	3.71	.915	3.12	1.214	0.738
A3-0	I feel passionate about the environment.	3.94	.826	3.38	1.248	0.804
Affective learning (AFF5): AVE = 0.847*		3.866	.899	3.872	.940	
A1-5	I feel excitement about the topic of ES	3.71	.997	3.71	1.11	0.945
A2-5	I feel eager to learn more about ES	3.79	1.126	3.71	1.08	0.939
A3-5	I feel passionate about the environment.	4.10	.799	4.19	.833	0.877
Behavioral learning (BEH1): AVE = 0.773*		3.279	.931	3.2202	.974	
B1-0	My behaviors related to the environment have changed.	3.44	1.018	3.36	1.100	0.831
B2-0	I did something new related to ES	3.08	1.082	3.07	1.113	0.875
B3-0	I made changes to my behavior related to ES	3.15	1.092	3.24	1.055	0.910
B4-0	I do things differently now with respect to ES	3.44	1.074	3.21	1.116	0.899
Behavioral learning (BEH5): AVE = 0.701*		3.506	1.101	3.607	.894	
B1-5	My behaviors related to the environment have changed.	3.83	1.004	3.64	1.008	0.805
B2-5	I did something new related to ES	3.35	1.235	3.57	1.063	0.861
B3-5	I made changes to my behavior related to ES	3.50	1.076	3.60	1.083	0.895
B4-5	I do things differently now with respect to ES	3.62	1.087	3.69	.924	0.903

Social learning (SL1): AVE = 0.797*		2.923	1.056	3.202	1.044	
S1-0	I talk to others about ES	2.92	1.234	3.17	1.228	0.909
S2-0	I educate others about ES	2.79	1.109	3.19	1.131	0.908
S3-0	I am confident discussing about ES with others	3.04	1.220	3.36	1.078	0.863
S4-0	I connect with other people regarding ES	2.94	1.178	3.10	1.246	0.890
Social learning (SL5): AVE = 0.765*		3.379	1.198	2.33	.704	
S1-5	I talk to others about ES	3.31	1.261	2.17	1.102	0.920
S2-5	I educate others about ES	3.37	1.268	2.57	1.172	0.869
S3-5	I am confident discussing about ES with others	3.52	1.244	2.26	1.106	0.826
S4-5	I connect with other people regarding ES	3.33	1.200	2.33	1.052	0.881
Behavioral Intention (INT1): AVE = 0.526*		3.77	0.77	3.428	.783	
I1-1	I intend to switch off my PC when not in use.	3.90	1.089	3.62	1.343	0.693
I2-1	I intend to reduce my water usage.	3.21	1.054	2.76	.906	0.725
I3-1	I expect to recycle waste as much as possible.	4.19	0.793	3.90	1.122	0.755
I4-1	I intend to switch off the lights when not required.	4.52	0.700	4.19	1.087	0.727
Behavioral Intention (INT5): AVE = 0.554*		4.196	.656	4.00	.685	
I1-5	I intend to switch off my computer when not in use.	4.17	.985	3.83	1.057	0.818
I2-5	I intend to reduce my water usage.	4.31	.805	4.02	.924	0.666
I3-5	I will recycle waste as much as possible	4.27	.744	4.21	.898	0.840
I4-5	I intend to switch off the lights when not required.	4.54	.727	4.43	.703	0.668

*Correlation is significant at the 0.05 level

C: Reliability values

Constructs	No. of items	Cronbach's alpha	rho-A	Composite reliability
Cognitive learning (COG1)	3	0.915**	0.917**	0.946**
Cognitive learning (COG5)	3	0.940**	0.944**	0.962**
Affective learning (AFF1)	3	0.635*	0.644*	0.801**
Affective learning (AFF5)	3	0.909**	0.910**	0.943**
Behavioral learning (BEH1)	4	0.902**	0.903**	0.932**
Behavioral learning (BEH5)	4	0.913**	0.917**	0.933**
Social learning (SL1)	4	0.915**	0.925**	0.940**
Social learning (SL5)	4	0.898**	0.914**	0.928**
Behavioral Intention (INT1)	4	0.704**	0.707**	0.816*
Behavioral Intention (INT5)	5	0.796**	0.813**	0.860**

* Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level

D: Fornell-Larcker test of discriminant validity

	AFF1	AFF5	BEH1	BEH5	COG1	COG5	INT1	INT5	SL1	SL5
AFF1	0.757									
AFF5	0.458	0.921								
BEH1	0.563	0.394	0.879							
BEH5	0.305	0.745	0.420	0.837						
COG1	0.508	0.360	0.648	0.347	0.924					
COG5	0.301	0.685	0.419	0.648	0.391	0.945				
INT1	0.319	0.535	0.477	0.451	0.363	0.436	0.725			
INT5	0.276	0.667	0.324	0.698	0.164	0.548	0.557	0.744		
SL1	0.525	0.545	0.663	0.474	0.607	0.318	0.422	0.289	0.893	
SL5	0.323	0.409	0.339	0.441	0.249	0.355	0.352	0.276	0.248	0.87

E: Correlation Matrices

Experiment(n=52)	INT1	COG1	AFF1	BEH1	SL1	INT5	COG5	AFF5	BEH5	SL5
INT1	1									
COG1	.463**	1								
AFF1	.497**	.637**	1							
BEH1	.644**	.611**	.596**	1						
SL1	.421**	.598**	.626**	.654**	1					
INT5	.544**	.189	.228	.437**	.168	1				
COG5	.478**	.440**	.295*	.540**	.266	.474**	1			
AFF5	.578**	.375**	.460**	.423**	.490**	.560**	.675**	1		
BEH5	.460**	.363**	.267	.478**	.441**	.655**	.601**	.688**	1	
SL5	.448**	.409**	.460**	.532**	.508**	.504**	.593**	.751**	.856**	1
Control (n=42)	INT1	COG1	AFF1	BEH1	SL1	INT5	COG5	AFF5	BEH5	SL5
INT1	1									
COG1	.338*	1								
AFF1	.056	.395**	1							
BEH1	.302	.707**	.526**	1						
SL1	.537**	.611**	.503**	.700**	1					
INT5	.539**	.141	.256	.177	.475**	1				
COG5	.377*	.332*	.280	.272	.416**	.620**	1			
AFF5	.517**	.328*	.469**	.337*	.613**	.772**	.698**	1		
BEH5	.540**	.301	.331*	.335*	.505**	.794**	.715**	.802**	1	
SL5	-.037	.106	-.022	.053	-.005	-.255	-.128	-.088	-.181	1

* Correlation is significant at the 0.05 level ; ** Correlation is significant at the 0.01 level

F: Interview Questions

1. Tell me about your experience while playing EnerCities - Free response.
2. Did you know about environmental sustainability before playing the game? - Give examples.
3. Talk about your learning experience - Free response
4. What are your perceptions now? - Give examples
5. What did you do after playing the game? - Give examples
6. What were some of the game features that helped you learn? - Give examples

G: Coding scheme

Codes	N	Code Frequency	Categories	Themes
Eco-aware already	2	3	Prior knowledge	
Fairly good knowledge	3	6		
Made me aware	4	10	New learning	
Learned nothing new	2	2		
Think of new ways	2	4		
Impactful new learning	9	15		Cognitive learning
Connect to real-world – pollution, factories consuming power, harmful actions.	7	17		
Complex system	3	5		
Visualization in game	9	12	Features in game	
Flexible in choices	3	6		
Self-instruction	1	3		
Playable format	7	7		
Challenging	6	11		
Prompts	7	10		
Affectively involved	9	25	Emotional	
Connect to real-world experiences	7	10		
Balance	9	15		
Alternate perspectives	2	3		
Think of other people	5	12		
Urgency to act	6	7		Affective learning
Happy and sad faces	8	18	Features in game	
Immersive environment	7	7		
Icons that showed – green cover, fossil fuels, resources	9	21		
Prior wrong behaviors	4	5	Performing actions	
Not mindful before	3	4		
Prior mindful behaviors	2	6		
New behaviors – unplug devices, watch media, monitor statistics, reduce energy use, recycle	9	24		Behavioral learning
No second chance	1	1		
Limitations to actions	6	8	Features in game	
Monitors	5	5		
Realistic	9	17		
	7	9		
Shared scores and learning	9	9	Share knowledge	
Shared game	1	1		
Did not share learning	2	2		
Willingness to share learning	9	9		Social learning

Scoring system	9	11	Features in game	
Competition	9	13		
Discussed smiley faces (emoticons)	8	8		
Consequences	9	17		
Energy needs of buildings	4	9		Real-life perspective
Recreation needs	2	3		
End of fossil fuels	1	2		
Life in other places	4	6		

H: R^2 values & Q^2 values with predictive relevance

Constructs	R^2	R^2 Adjusted	Q^2
Cognitive learning (COG5)	0.153	0.143	0.125 (medium)
Affective learning (AFF5)	0.209	0.201	0.158(medium)
Behavioral learning (BEH5)	0.176	0.168	0.112 (medium)
Social learning (SL5)	0.062	0.051	0.039 (Small)
Behavioral Intention (INT1)	0.249	0.215	0.101 (small)
Behavioral Intention (INT5)	0.636	0.597	0.311 (med-high)

I. Path coefficients – Multi Group Analysis (MGA)

	Control group				Experiment group			
Paths	Path coefficients	p-Values	Lower bound	Upper bound	Path coefficients	p-Values	Lower bound	Upper bound
AFF0>INT1	-0.269	0.136	-0.709	0.028	0.275	0.153	-0.107	0.634
AFF0>INT5	0.035	0.822	-0.371	0.240	0.151	0.438	-0.205	0.551
AFF0>AFF5	0.492	0.000	-0.081	0.667	0.493	0.000	0.166	0.710
AFF5>INT5	0.359	0.153	-0.150	0.836	0.362	0.095	-0.085	0.762
BEH0> INT1	-0.114	0.621	-0.563	0.346	0.597	0.001	0.249	0.921
BEH0> INT5	-0.123	0.467	-0.588	0.122	0.362	0.066	0.001	0.766
BEH0>BEH5	0.353	0.032	-0.097	0.610	0.491	0.000	0.253	0.656
BEH5> INT5	0.434	0.017	0.136	0.890	0.729	0.002	0.274	1.191
COG0>INT1	0.060	0.706	-0.250	0.377	-0.040	0.820	-0.344	0.361
COG0>INT5	-0.125	0.384	-0.420	0.130	-0.162	0.365	-0.473	0.228

COG0>COG5	0.336	0.063	-0.076	0.631	0.448	0.001	0.164	0.678
COG5>INT5	0.015	0.923	-0.311	0.289	-0.127	0.494	-0.444	0.282
SL0 > INT1	0.747	0.000	0.336	1.061	-0.166	0.339	-0.515	0.167
SL0 > INT5	0.147	0.500	-0.272	0.608	-0.421	0.008	-0.802	-0.154
SL0 > SL5	-0.136	0.643	-0.475	0.537	0.510	0.000	0.270	0.689
SL5 > INT5	-0.082	0.527	-0.284	0.242	-0.400	0.109	-0.963	0.025

J. Structural model results and hypotheses tests

Hypotheses	Path Coefficients	Path Coefficient difference (Experiment - Control)	p-value (Experiment Vs Control)	Accept/reject hypotheses
H1	AFF0>INT1	0.544	0.044*	Accept
H2	AFF0>INT5	0.186	0.468	Reject
H3	AFF0>AFF5	0.001	0.997	Reject
H4	AFF5>INT5	0.003	0.994	Reject
H5	BEH0>INT1	0.711	0.013*	Accept
H6	BEH0 > INT5	0.485	0.069	Reject
H7	BEH0 > BEH5	0.139	0.451	Reject
H8	BEH5 > INT5	0.295	0.339	Reject
H9	COG0 > INT1	0.101	0.678	Reject
H10	COG0 > INT5	0.037	0.875	Reject
H11	COG0 > COG5	0.111	0.612	Reject
H12	COG5 > INT5	0.142	0.565	Reject
H13	SL0 > INT1	0.913	0.000**	Accept
H14	SL0 > INT5	0.569	0.032*	Accept
H15	SL0 > SL5	0.646	0.027*	Accept
H16	SL5 > INT5	0.318	0.290	Reject

* Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level

CHAPTER 3. EXPLORING THE EFFECTIVENESS OF DIGITAL GAMES IN PRODUCING PRO-ENVIRONMENTAL BEHAVIORS WHEN PLAYED COLLABORATIVELY AND INDIVIDUALLY: A MIXED METHODS STUDY IN INDIA

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Abstract

Environmental sustainability education should create eco-awareness and produce pro-environmental behaviors. Traditional instructional methods create eco-awareness but do not make people act. Purposefully designed digital games for attitudinal instruction provide cognitive knowledge, engage learners emotionally by showing the consequences of harmful behaviors, and encourage correct behaviors. Most studies involving games in different subjects showed that knowledge acquisition was greater in collaborative learning than individual game play. However, a similar comparison with respect to attitudinal learning involving a socio-scientific topic has not been conducted before. This mixed methods study conducted in a high school in India, examined the attitudinal learning among students who played a game individually (n=45) and collaboratively (n=44). Also, differences between students who played the game and a control group (n=42) was examined. Surveys based on the Theory of Planned Behavior (TPB) and the Attitudinal Learning Instrument (ALI), showed that attitudinal learning from games was similar for collaborative and individual players. Also, attitudinal learning from games was higher compared to traditional

instructional methods. Interviews explained the learning experiences of game players and how it produced pro-environmental behaviors.

Keywords: Attitudinal learning, digital games, eco-awareness, pro-environmental behaviors, environmental sustainability

Introduction

Melting polar ice, temperature departures, and climate change across the globe (Brinkman, 2020; Osiode, 2020; Vorkinn & Riese, 2001) have made most people eco-aware. However, people fail to recognize that the main cause is human induced (anthropocentric) changes to atmospheric composition (Karl & Trenberth, 2003; Meya & Eisenack, 2018). Even pandemics like COVID-19 are due to zoonotic transmission of diseases from animals to humans caused by alteration to natural habitats (UNEP, 2020). However, this knowledge does not encourage pro-environmental behaviors. Researchers and policy makers studied how individual attitudes and beliefs inform and affect pro-environmental decisions and actions (Amburgey & Thoman, 2011; Jowett et al., 2014; Rideout, 2013) and have prescribed environmental sustainability education as a solution (Meya & Eisenack, 2018; UNESCO, n.d).

Sustainability education needs to create awareness in K-12 students (Buchanan et al., 2016) because they are the citizens of the future (Fielding & Head, 2012). Education should promote mindfulness (Wang et al., 2017), be persuasive in order to change attitudes and behaviors (Griset, 2010; Sinatra et al., 2012), and be interactive (Meya & Eisenack, 2018) and adapted to needs of young students. UNESCO (2019) emphasizes the need to design "learning in an interactive, learner-centred way that enables exploratory, action oriented and transformative learning," that would inspire learners to act sustainably (para. 3). In this context, digital games can serve as effective pedagogical tools (Harker-Schuch et al. 2020; Wu & Huang, 2015; Yang et al., 2012) because they can encourage exploration and experimentation when used purposefully by teachers and parents as "objects-to-think-with" (Holbert & Wilensky, 2019).

Many prior studies using educational games showed that collaborative efforts are more beneficial in learning compared to individual efforts (Hsiao et al., 2014; Prez & Guzman-Duque, 2014), while some studies contradict that (Plass et al. 2011; Weinberger et al., 2005). This has not been studied in attitudinal learning using environmental education games. In this exploratory mixed-methods study, the influence of digital games in producing pro-environmental attitudes and

behaviors when played collaboratively and individually by high school students was examined using the Theory of Planned Behavior (TPB; Ajzen, 2019). The Attitudinal Learning Instrument (ALI) was used to measure attitudinal learning.

According to the TPB, if people have a more favourable attitude towards a behavior and think that the social environment desires the performance of that behavior and if they perceive that they can perform that behavior, then it is more likely that they will have an intention to perform that behaviour (Ajzen, 2019). In most cases, people believe that they do not have control over pro-environmental behaviors despite being eco-aware, and hence did not translate intentions into actual behaviors. This is where digital games can serve as persuasive pedagogical tools in encouraging pro-environmental behaviors among young learners.

This exploratory mixed methods study was conducted in a high school in India where Environmental Studies (EVS) is taught using traditional methods of instruction. First, the effectiveness of digital games in influencing pro-environmental behaviors when played collaboratively (n=44) and individually (n=45) was examined based on the TPB and ALI. Secondly, the effectiveness of games in EVS was examined by comparing all game players (n=89) with a control group (n=42), that did not play the game. Partial Least Squares-Structural Equation Modelling (PLS-SEM) was used to analyse the survey data. Thirdly, the perceptions of game players to their attitudinal learning experience was examined qualitatively. This study provides implications for digital game adoption and implementation in teaching EVS in K-12 schools.

Literature Review

EVS for Attitude Change

Environmental studies (EVS) encompasses learning about sustainable relations between people, the bio-physical world and the non-human world (Huckle, 2012). This definition covers cognitive knowledge or eco-awareness that deals with one component of attitude. However, EVS should address all three components of attitude to be effective in producing pro-environmental behaviors. Attitude is the psychological evaluation a person has about an object, person or event (Gagne, Briggs, & Wagner, 1992) and is comprised of three components (Kamradt & Kamradt, 1999): the cognitive component (information, knowledge and thoughts); the affective component (emotions and feeling), and the behavioral component or the pre-disposition to act (Kamradt &

Kamradt, 1999; Simonson, 1979). Social learning is another aspect of attitude change, where interaction with others influences attitudes (Watson et al., 2018). Hence EVS focusing on attitudinal learning should address all the four components of attitude.

EVS should reduce learners' perceived separation between self and nature (Schultz, 2000), develop a sense of ownership and empowerment (Hungerford & Volk, 1990), and develop empathy (Berenguer, 2007; Pfattheicher et al., 2015) by perspective taking (Pahl & Bauer, 2011). EVS should encourage pro-environmental actions irrespective of barriers and constraints (Arbuthnott, 2009; Tucker, 1999) and should be persuasive (Sinatra et al., 2012) to increase environmental concern.

Games in EVS

Educational digital games are popular with children because they create a student-centered environment (Gros, 2014; Watson et al., 2011), and facilitate situated understanding (Gee, 2008). Games promote scientific problem solving (Wen et al., 2018), are intrinsically motivating (Gee, 2007; Habgood & Ainsworth, 2011; Prensky, 2003) and are therefore suitable for EVS (Bell, 2016; Cheng et al., 2013; Cuccurullo et al., 2013). They can create feelings of empathy, provide a discovery learning environment, help visualize the interrelatedness of the environment, and promote systems thinking (Fabricatore & López, 2012; Harker-Schuch et al., 2020; Liarakou et al., 2011; Nordby et al., 2016; Yoon et al., 2017). Games increase players' knowledge of sustainability issues and sustainable development strategies (Janakiraman et al., 2018; Katsaliaki & Mustafee, 2014) by making them perform actions that may be inconsistent with their existing attitude and slightly consistent with the target attitude (Kamradt & Kamradt, 1999). This causes an uncomfortable psychological tension (cognitive dissonance), that forces people to change their beliefs or behaviors (Watson et al., 2018; Festinger, 1957). Instant feedback through prompts (Zumbach et al., 2020), not possible in real environments, help players connect decision-making in the game to real life (Yang et al., 2012; Wu & Huang, 2015). These realistic scenarios give meaningful practice before facing the real action influencing pro-environmental attitudes and behaviors (Butler, 1988; Knol & De Vries, 2011; Tan & Biswas, 2007).

Collaborative Vs Individual Game Play

Collaboration enables two or more people to share and co-construct knowledge while solving a problem (van der Meij et al., 2011). In comparison to individual efforts, collaboration appears to promote inquiry learning, problem solving, and critical thinking because students can explain their thinking, verbalize it, collaborate and engage in joint elaboration on their decision making (Harding et al., 2017; Kirschner et al., 2018; Mullins et al., 2011; Nurhaniyah et al., 2015; Tan, 2018). The cognitive load or the total working memory resources that is required to carry out a learning task (Leahy & Sweller, 2011; Sweller, 2010), is shared among team members while processing complex material improving information processing and understanding (Kirschner et al., 2018). Rader et al. (2014) showed in a study, using a virtual reality simulator to teach complex clinical skills to medical students, that learning in dyads or pairs was more efficient and cost-effective.

Collaboration in games is of two types: (i) team members are able to engage in the virtual space and interact on multi-player multi-modal display screens (Hsiao et al., 2014; Rick et al., 2009). Collaboration can also happen virtually in an online game when players are represented within the game (Prez & Guzman-Duque, 2014), (ii) team members engage in the real space to take decisions, while taking turns to operate the mouse to perform actions on the game screen that the team agrees upon (Stanton & Neale, 2003).

Prior studies have shown mixed results for individual and collaborative game play. Playing a History game in groups of 3-4 produced greater engagement, active participation, and hands-on fun, when players took turns to operate the mouse (Watson et al., 2011). In an online game, team players were successful in decision-making, problem solving, and developing strategies while playing the CityVille game collaboratively (Prez & Guzman-Duque, 2014). Collaboration improved learning performance and retention in an eco-friendly lifestyle game, where individual players did not get immediate feedback for their actions (Hsiao et al., 2014). Collaboration in Group Scribbles (GS) a Mathematics game enhanced problem-solving and helped low-ability students gain more confidence in performing Math calculations (Chen et al., 2012). The attributes and interactivity of virtual environments establishes a “community of learners” where groups learn together “using each other’s knowledge, skills, experiences and resources,” (Hanewald, 2013, p. 234), especially when competitiveness is reduced and dependency by providing shared goals is

increased between game players (Scoular et al., 2017). Since collaboration is a key component of problem-based learning, it should be used in games for learning, noted Watson and Fang (2012).

However, Plass et al., (2013) found that collaborative play resulted in inefficient problem-solving strategies and errors in a Mathematics game, although increasing enjoyment. Some studies have shown that games do not enhance learning but instead cause cognitive overload owing to distractions (Adams et al., 2012; Mayer, 2005) and may not actually result in more knowledge gain (Linderoth, 2012).

The above studies concern knowledge gain using games in various subjects, however, there is a dearth in studies that explore the influence of collaboration through games on attitudinal and behavioral learning concerning EVS. This mixed methods study strives to close that gap.

Theory of Planned Behavior (TPB)

It is not easy to measure environmentally friendly behaviors because it requires sustained observations, and intentions may not translate into behaviors immediately after an intervention owing to several reasons. According to the TPB (Ajzen, 2019) it is important for a person to have, "sufficient degree of actual control over the behavior," in order to translate their intentions into actual behaviors when they get an opportunity, and that intention is "assumed to be the immediate antecedent of behavior" (p. 1). Ajzen (2019) explains that three types of considerations guide any human behavior: beliefs about the likely consequences of the behavior (behavioral beliefs) that produces a favorable or unfavorable attitude toward the behavior (ATB); beliefs about the normative expectations of others (normative beliefs) that result in perceived social pressure (SOP) or subjective norm, and beliefs about the presence of factors that may facilitate or impede performance of the behavior (control beliefs) that gives rise to perceived behavioral control (PBC). Furthermore, the effects of ATB and SOP on intention are moderated by PBC (Ajzen, 2019, p.1) and hence PBC can be considered in place of actual control to predict the behavior. See Figure. 5.

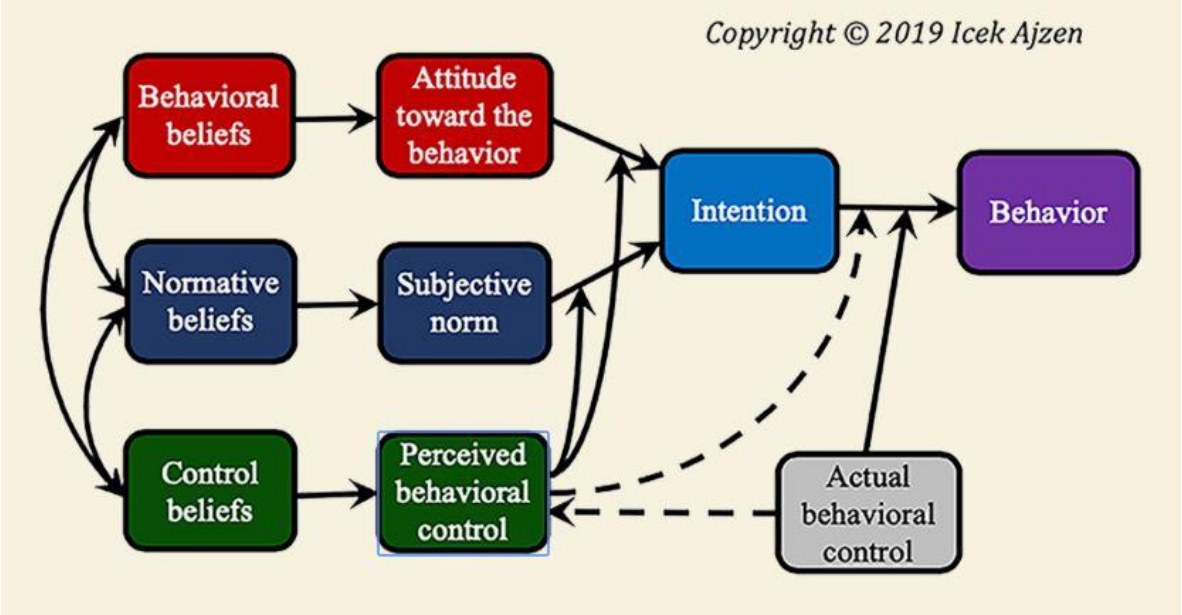

Figure 5. TPB Model (Ajzen, 2019)

Study Context

This study was conducted in Kozhikode, a coastal city in the southern state of Kerala, India. Kerala generally has a moist and wet climate receiving excessive seasonal rainfall. However, in recent years floods and periods of drought have affected people in Kozhikode and the rest of the state. Rapid urbanization, unauthorized borewells, depletion of natural resources like forest cover, and reduced natural water conservation facilities are some reasons leading to the droughts (Economic Times, 2019). City data about Kozhikode shows moderate to high levels of air, water, noise, and light pollution (Numbeo, 2020). Participants in this study were well aware of their environment, through media, school, and community programs. Furthermore, all participants had studied Environmental Studies (EVS) from grade three. The objectives of EVS are to help students identify environmental problems and the interactive processes of nature, and how to care for the environment, prevent pollution, conserve energy, and preserve the environment.

The goal of this study was to explore if there were any differences in attitudinal and behavioral learning from a game designed for EVS between collaborative game players and individual game players, and between game players and a control group. The perceptions of both collaborative and individual games players to their learning experience were also examined. Institutional Review Board (IRB) permission was obtained before conducting this study.

In this exploratory mixed-methods study the Theory of Planned Behavior (Ajzen, 2019) was used to explain the pro-environmental attitudes and behaviors of the participants. The ALI was used to measure attitudinal learning and to examine the differences between collaborative and individual players. Interviews provided insights into game play experience and its influence on attitudes and behaviors, supporting the quantitative findings of this mixed methods study. Specifically, the research questions were:

RQ1: (a) Are digital games more effective in influencing pro-environmental behaviors when played collaboratively or when played individually as explained by the TPB Model?

(b) Are digital games more effective in influencing pro-environmental behaviors compared to traditional EVS educational methods as explained by the TPB model?

RQ2: Are digital games more effective in producing attitudinal learning when played collaboratively or when played individually as measured using the ALI?

RQ3: What were students' perceptions of their game play experience?

Methods

Research Design

An Embedded Mixed Methods research design (Creswell & Clark, 2017) comprising two phases was employed in this exploratory: quantitative data was collected first, and qualitative data was collected next as shown in Figure 6. Embedded designs offer unequal priority to the quantitative and qualitative components (Plano Clark et al., 2013). RQ1 and RQ2 are the primary questions (quantitative approach), while RQ3 is the secondary question (qualitative approach). Answering RQ3 enhances the research design and the interpretation of the quantitative data.

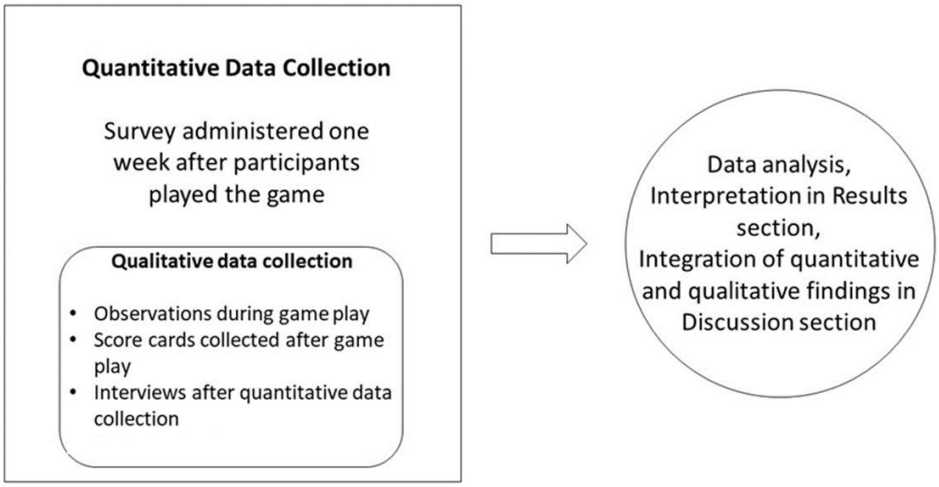

Figure 6. Mixed-Methods research design

Participants. The data was collected from three sections of students studying in grade 11 (aged 16-17) in Kozhikode, India. One group (n = 45) played the game by themselves (individual group). Another group (n = 44) played the game in teams of two (collaborative group). The game used in this study was not built as a collaborative game, that allows collaboration within the virtual space of the game. In this study type (ii) of collaboration as described in the literature review was used. Team members performed actions that the team agreed upon, by taking turns to operate the mouse (Stanton & Neale, 2003; Watson et al., 2011) and earn scores for the actions they performed collaboratively. The space between the rows of computers was limited and did not allow more students to sit together in front of one computer, hence the groups were restricted to two members. The control group (n = 42) participants did not play any game. All participants were taught EVS through traditional methods from grade 3 to 5 as a dedicated subject and for higher grades as part of other subjects. The objectives of EVS are to help students identify environmental problems and the interactive processes of nature, and how to care for the environment, prevent pollution, conserve energy, and preserve the environment. IRB permission was obtained before conducting this study.

Game Context. van der Meij et al., (2011) emphasize the need to implement only games that "have proven their worth for yielding learning outcomes" (p. 656). EnerCities, the game used

in this study was designed to teach about renewable and non-renewable sources of energy and features all components of EVS. It is a 3D game created by Qeam with support from University of Twente and partners to be implemented for EVS in European schools (Knol & DeVries, 2010; 2011). EnerCities was played on computers pre-loaded with the game. Students were encouraged to play 2-3 times. Total time provided was 50 minutes. Players were required to perform activities that are not part of their daily lives (Meya & Eisenack, 2018).

In the game, players created a virtual sustainable city, that matched a real-world scenario with houses, buildings, stadiums, marketplaces etc. Players performed activities that are not part of their daily lives (Meya & Eisenack, 2018). They constructed new houses to increase the population and their game scores, by balancing the natural resources like fossil fuels, monetary reserves, and power supply. Reaching a particular population helped them 'level up' in the game and gain higher scores. At the same time players had to implement more renewable sources of energy, make all buildings comply with green standards, and protect the greenery of the city to keep the virtual citizens of the city happy, otherwise the scores dropped drastically. In addition, there were several monitors that indicated the levels of money, fuel, and power that also impacted the scores. Citizens' happiness was indicated by a smiley face that turned sad, and a green tree icon that turned red when environmental degradation set-in, indicating wrong actions immediately. Players had to keep an eye on the scores and all these monitors to see how well they progressed. They were allowed to demolish and re-build parks, buildings, and power plants to balance the monitors and earn more points.

Players were guided by text information that appeared when any icon was clicked. These icons placed in several locations provided cognitive knowledge. For example, clicking on the power icon provided different options to generate power, each with information about where to install, the cost involved, the advantages, and so on. The real-life complex situation immersed players and helped them learn about how wrong decisions can hasten environmental degradation, reduce citizens' happiness, and create economic failures. This facilitated affective learning. Testing of behaviors and seeing consequences immediately, facilitated behavioral learning.

To be successful in the game, players had to strategize and economically build a sustainable city with happy citizens, enough forests and parks, and buildings that were energy efficient by implementing a judicious mix of renewable and non-renewable sources of energy. On reaching higher levels, players were rewarded with upgrades to buildings, more energy options, and more

money. A game score card was generated at the end of the game that indicated how well a player balanced the economy, citizens' wellbeing, and the environment. Figure 7 shows an instance of game play with indicators and icons.

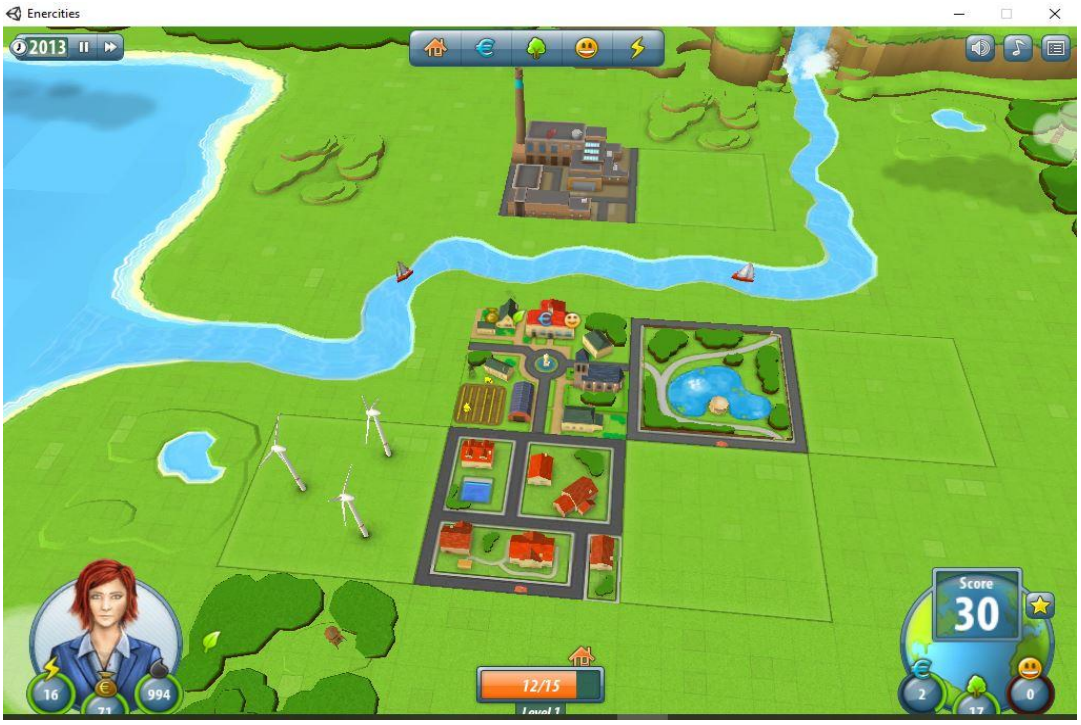

Figure 7 . EnerCities game screen showing indicators

Data Collection and Analysis

Quantitative Phase

After one week of game play, data was collected through a survey with items from the Attitude Learning Instrument (ALI; Watson et al., 2018) and items based on TPB that was administered to all three groups at the same time. There were 16 items based on TPB (Ajzen, 2019; De Vries & Knol, 2011; Greaves et al., 2013), and 14 items based on ALI. As a self-reflection instrument, ALI measures learner perceptions of attitudinal learning after any type of intervention (Watson et al., 2018; Watson et al., 2020). The items measure cognitive (3 items), affective (3 items), behavioral (4 items), and social (4 items) learning using a 5-point scale. See Appendix A for list of survey items.

Quantitative data analysis was executed in three steps.

Step 1: The causal-predictive approach of Partial Least Squares-Structural Equation Modelling (PLS-SEM) was used for data analysis and hypothesis testing (Hair et al., 2019) to explore the structural model based on the TPB (See Figure 8). Using the SmartPLS 3.0 software package PLS-SEM bootstrap was executed taking 2000 subsamples to examine if the structural model fits the data.

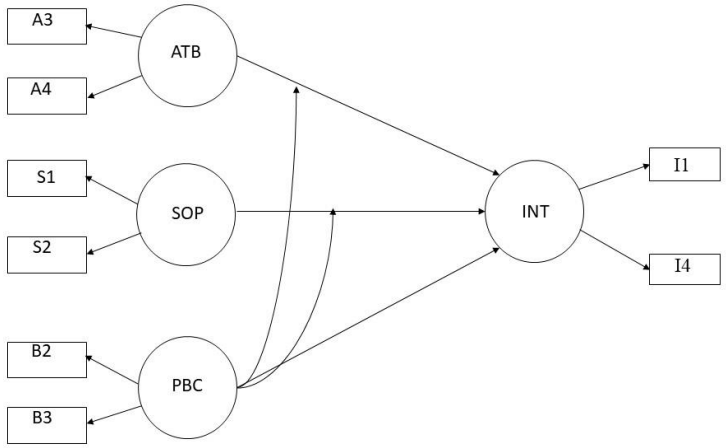

Figure 8. TPB model based on schematic representation of the TPB theory (Ajzen, 2019)

In Figure 8: A3, A4 are indicator survey items in the TPB survey, related to attitude towards behavior (ATB), S1 & S2 for social pressure (SOP), and B2 & B3 for perceived behavioral control (PBC). ATB, SOP and PBC explain the Behavioral intentions (INT) after a week of playing the game. I1 & I4 are indicator survey items for INT. The moderating effect of PBC on ATB and SOP (Ajzen, 2019) is shown in Figure 5. The following were the hypotheses based on TPB (Ajzen, 2019).

H1: Influence of ATB on INT after a week of game play is greater for Collaborative players.

H2: Influence of SOP on INT after a week of game play is greater for Collaborative players.

H3: Influence of PBC on INT after a week of game play is greater for Collaborative players.

The sample size of 89 exceeded the required minimum sample size of 65 and determines that the proposed SEM model fits the data to achieve a statistical power of 80% to detect R^2 values of at least 0.25 (Benitz et al., 2019; Hair et al., 2016). In most cases the indicator loadings were

greater than the recommended value of 0.708 for each indicator/construct, explaining more than 50% of the indicator's variance and ensuring acceptable item reliability (See Table 2). The lower values are not problematic because the construct validity and reliability criteria were met (Benitez et al., 2019).

Table 2: TPB measurement model assessment (Individual Vs Collaborative)

Indicator Code	Construct/Indicator (survey items)	Individual (n=45)		Collaborative (n=44)		Loading
		Mean	SD	Mean	SD	
Attitude towards behavior (ATB)						
A1	Recycling waste as much as possible is worthwhile.	3.88	.77	3.88	1.11	0.67
A2	Switching off the lights when I leave an unoccupied room is good.	3.79	1.18	4.15	.95	0.91
Social pressure (SOP)						
S1	I am under great pressure to switch off the computer when not using it for some time.	3.56	1.02	2.95	1.30	0.84
S2	People I live with (like parents and other family members) expect me to use less water.	3.53	1.13	3.55	1.09	0.57
Perceived behavioral control (PBC)						
B2	The decision to switch off my laptop when not in use is purely my decision.	3.88	1.18	3.93	1.27	0.93
B3	Switching off the lights when leaving a room is within my control.	4.06	1.01	3.37	1.38	0.70
Behavioral intention (INT)						
I1	I intend to switch off my PC when not in use	4.21	.85	4.2	.88	0.81
I2	I intend to switch off the lights when not required.	3.15	.99	3.30	1.24	0.86

The composite reliability values ranged between 0.67 and 0.82 for all indicators (Table B) indicating that internal consistency reliability requirements were met. The extent of convergence of construct measures were provided by the average variance extracted (AVE) values that were higher than the recommended value of 0.50 (see Table 3). All constructs were empirically distinct from the other constructs in the structural model (discriminant validity) according to the Fornell-Larcker criterion. Also, there were no multicollinearity issues. Hence, item reliability, internal composite reliability, convergent validity and discriminant validity were established for the TPB measurement model. The above analysis shows that the proposed model fits the data.

Table 3: TPB Model - Reliability values

Constructs	No. of items	Composite reliability	Average Variance Extracted (AVE)
Attitude towards behavior (ATB)	2	0.78*	0.64*
Social pressure (SOP)	2	0.67	0.52*
Perceived behavioral control (PBC)	2	0.79*	0.66*
Behavioral Intention (INT)	2	0.82*	0.69*

* Correlation is significant at the 0.05 level

Step 2: To compare pro-environmental behaviors of game players and the control group using the TPB, individual and collaborative game players data were combined (n=89) and were compared with the control group (n=42). The measurement model was assessed for fit with data (See Tables 4 and 5). The sample size, item reliability, internal composite reliability, construct validity and discriminant validity were established for the measurement model.

Table 4: TPB measurement model assessment (Game players Vs Control group)

Code	Construct/Indicator (survey items)	Game (N=89)		Control (N=42)		Loading
		Mean	SD	Mean	SD	
Attitude towards behavior (ATB)						
A1	Recycling waste as much as possible is worthwhile.	4.59	0.55	4.17	0.99	0.53
A2	Switching off the lights when I leave an unoccupied room is good.	4.69	0.64	4.43	0.83	0.97
Social pressure (SOP)						
S1	I am under great pressure to switch off the computer when not using it for some time.	3.23	1.21	2.98	1.05	0.95
S2	People I live with (like parents and other family members) expect me to use less water.	3.54	1.10	3.83	0.96	0.40
Perceived behavioral control (PBC)						
B2	The decision to switch off my laptop when not in use is purely my decision.	3.91	1.22	3.81	0.89	0.89
B3	Switching off the lights when leaving a room is within my control.	3.69	1.26	3.81	1.11	0.74
Behavioral intention (INT)						
I1	I intend to switch off my PC when not in use	4.20	0.86	3.93	0.78	0.83
I2	I intend to switch off the lights when not required.	4.41	0.77	4.33	0.72	0.85

Table 5: TPB Model - Reliability values

Constructs	No. of items	Composite reliability	Average Variance Extracted (AVE)
Attitude towards behavior (ATB)	2	0.74*	0.61*
Social pressure (SOP)	2	0.63	0.51*
Perceived behavioral control (PBC)	2	0.80*	0.66*
Behavioral Intention (INT)	2	0.83*	0.70*

* Correlation is significant at the 0.05 level

Step 3:To examine attitudinal learning when played collaboratively and individually based on the ALI instrument, the model in Figure 9 was proposed. C1, C2, C3 are indicator survey items in the ALI, explaining the cognitive learning (COG), A1, A2, & A3 for affective learning (AFF), B2, B3, & B4 for behavioral learning (BEH) and S1, S2, & S3 for social learning (SL) achieved from the game when measured after one week. I1, & I2 are indicator variables that explain behavioral intentions (INT) one week from game play.

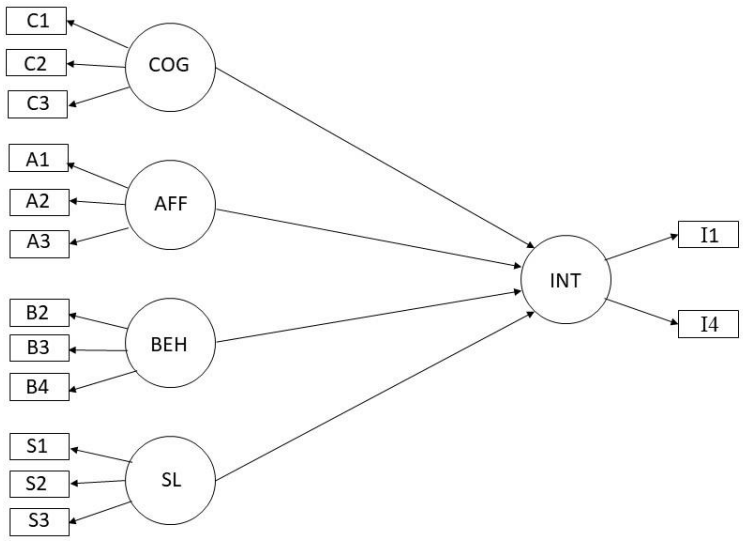

Figure 9. ALI model based on the Attitudinal Learning Instrument (ALI)

Each path in the structural model in Figure 9 denotes a hypothesis.

H1: Influence of AFF on INT after a week of game play is greater for Collaborative players.

H2: Influence of BEH on INT after a week of game play is greater for Collaborative players.

H3: Influence of COG on INT after a week of game play is greater for Collaborative players.

H4: Influence of SL on INT after a week of game play is greater for Collaborative players.

The final sample size of 89 exceeded the required minimum sample size of 65. The proposed ALI structural model was assessed by executing PLS-SEM bootstrap taking 2000 subsamples. The indicator loadings were higher than the recommended value of 0.708 in most cases, indicating acceptable item reliability (Table 6). See Table 7 for internal composite reliability, and construct validity. There were no multicollinearity issues. The above analysis indicates that the proposed model fits the data.

Table 6: ALI measurement model assessment

Code	Construct/Indicator (survey items)	Individual (N=45)		Collaborative (N=44)		Loading
		Mean	SD	Mean	SD	
Cognitive learning (COG)						
C1	I learned new information about the environment.	3.56	0.95	3.91	0.87	0.70
C2	I am more knowledgeable about EVS.	3.17	1.00	3.30	1.10	0.69
C3	I picked up new ideas about EVS.	3.41	0.87	3.49	1.08	0.91
Affective learning (AFF)						
A1	I feel excitement about the topic of EVS	3.71	1.08	4.16	0.79	0.79
A2	I feel eager to learn more about EVS	3.61	0.95	3.98	1.01	0.95
A3	I feel passionate about the environment.	4.02	0.88	4.05	0.87	0.78
Behavioral learning (BEH)						
B1	I did something new related to EVS	3.39	0.86	3.63	0.90	0.78
B2	I made changes to my behavior related to EVS	3.24	0.80	3.49	1.00	0.93
B3	I do things differently now with respect to EVS	3.61	0.74	3.53	1.00	0.80
Social learning (SL)						
S1	I talk to others about EVS	2.93	0.99	3.23	1.08	0.93
S2	I educate others about EVS	2.88	0.87	3.09	0.97	0.87
S3	I am confident discussing about EVS with others	3.29	0.96	3.77	1.08	0.70
Behavioral Intention (INT)						
I1	I intend to switch off my PC when not in use.	4.07	0.93	4.26	0.88	0.62
I2	I intend to reduce my water usage.	3.17	1.02	3.37	1.25	0.89

Table 7: ALI Model - Reliability values

Constructs	No. of items	Composite reliability	Average Variance Extracted (AVE)
Cognitive learning (COG)	3	0.82*	0.60*
Affective learning (AFF)	3	0.88*	0.71*
Behavioral learning (BEH)	3	0.88*	0.70*
Social learning (SL)	3	0.87*	0.70*
Behavioral Intention (INT)	2	0.73*	0.59*

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Qualitative Phase

Multiple evidences were used: (1) Observations by one researcher when participants played EnerCities. (2) Game scorecards generated at the end of the game. (3) Interviews conducted after the surveys. Only game players participated in semi-structured interviews because the goal was to find out about learning experiences from EnerCities to answer RQ2 (Plano Clark et al., 2013). The interview sample was selected based on the scores earned by the participants. Scorecards were generated automatically when the game ended and scores depended on the Level reached in the game, and the balance achieved in the amount of resources, green cover and citizens' happiness.

Two girls, one high scorer and one low scorer, and two boys, one high scorer and one low scorer were picked from both groups (n=8). This kind of intensity sampling provided "excellent or rich examples of the phenomenon of interest," revealing "the nature of success or failure" excluding extreme cases (Patton, 1990, p. 171). All interviews were audio-recorded, transcribed verbatim, and stored on password-protected computers.

The interview data was coded using a deductive approach in the first cycle starting with a list of a priori codes (Miles & Huberman, 2020): attitude, social norms, behavioural control, prior knowledge, attitudinal learning and behaviors. Subsequently, the codes were revised based on empirical data (Miles & Huberman, 2020) to include cognitive, affective, behavioral and social learning; game play experiences including decision making, role play, expectation, confidence, and pro-environmental behaviors. These were grouped into broad themes to understand and explain the learning experiences. The qualitative data or the embedded component may not be independent of the larger study context but provides additional knowledge that is linked to the primary aims of the study and is hence critical to the present study (Plano Clark et al., 2013).

Validity

Analyzing and reporting about the study using both qualitative and quantitative data ensured methods triangulation (Denzin, 1970). Using multiple sources of data from surveys, interview and digital artefacts established data triangulation (Denzin, 2012; Lincoln & Guba, 1985; Miles & Huberman, 1994) and multiple researchers established investigator triangulation (Denzin, 1978) and provided research rigor (Denzin, 1978; Patton, 2015). SmartPLS software helped establish reliability, construct validity, non-collinearity and discriminant validity of the

quantitative data. Qualitative data was collected after the quantitative data was collected to avoid bias and to ensure internal validity (Plano Clark et al., 2013).

Results

The quantitative and qualitative data were analyzed "separately to address the different research questions" (Plano Clark et al., 2013, p. 223) and the derived results are presented below answering each research question (RQ).

Explanation Using TPB Model

RQ1a: The PLS-SEM results were evaluated as the measurement model assessment was satisfactory for the TPB Model. R^2 value = 0.40 (R^2 Adjusted = 0.36) provided the explanatory power of the structural model showing substantial power (Benitz et al., 2019). ATB, PBC and INT had positive predictive relevance or Q^2 values (Shmueli et al., 2016), indicating predictive relevance of the construct indicators.

First, Multi-group Analysis (MGA) was executed to examine if there were differences in the ATB, SOP and PBC between individual and collaborative players. Based on the hypothesis, the structural model results (Ringle et al., 2015) were investigated for any significant differences in path coefficients. Result: There were no significant differences between individual and collaborative players considering ATB, SOP and PBC in influencing behavioral intentions (INT).

Since there were no differences between the groups, data from individual and collaborative game players (n=89) was combined and PLS-SEM bootstrap was executed taking 2000 subsamples. Result: ATB, PBC and SOP significantly influenced INT (Table 8) when the mediating effect of PBC on ATB and SOP were taken into consideration in accordance with the TPB Model (Figure 8; Ajzen, 2019).

Table 8: TPB model - All game players combined

	Path Co-efficient	P Values
ATB > INT	0.39	0.00**
PBC > INT	0.22	0.04*
SOP > INT	0.26	0.03*

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

RQ1b: Next, the combined group of game players (n=89) was compared with the control group (n=42) students who studied EVS only through traditional instructional methods and did not get the game intervention. The explanatory power R^2= 0.17 (R^2Adjusted = 0.13) indicated moderate power, considering that this is an exploratory study (Benitz et al., 2019). The predictive relevance or Q^2 values were positive for ATB, PBC and INT.

Multi-Group Analysis (MGA) was executed to examine any differences based on TPB between the game players and control group, based on following hypotheses.

H1: Influence of ATB on INT will be greater for game players.

H2: Influence of PBC on INT will be greater for game players.

H3: Influence of SOP on INT will be greater for game players.

Results: the influence of ATB on behavioral intentions (INT) for participants who played the game was significantly higher than participants who did not play the game based on the PLS MGA test results (See Table 9).

Table 9: TPB measurement model results and hypotheses tests (Game players Vs Control)

Hypotheses	Path Coefficients	Path Coefficient difference (Game Vs Control)	p-value (Game Vs Control)	Accept/reject hypotheses
H1	ATB>INT	0.73	0.00**	Accept
H2	PBC>INT	0.13	0.49	Reject
H3	SOP>AFF	0.38	0.11	Reject

** Correlation is significant at the 0.01 level

Attitudinal Learning Based on the ALI

RQ2: The PLS-SEM results can be evaluated as the measurement model assessment was satisfactory for the ALI Model. $R^2 = 0.22$ (R^2 Adjusted = 0.18) indicated substantial explanatory power of the structural model. The predictive relevance or Q^2 values were positive indicating small to high predictive relevance of all the construct indicators.

Multi-group Analysis (MGA) was executed to examine if there were differences in the influences of attitudinal learning on behavioral intentions between individual and collaborative game players. Result: There were no significant differences between individual and collaborative game players with respect to attitudinal learning.

Learning Experiences

RQ3: Qualitative data analysis explained the learning experiences of participants who played EnerCities collaboratively and individually.

Collaborative game play

Observations. Collaborative players read the instructions in the game, discussed and strategized their efforts from the beginning, and showed total engagement. Players took turns to operate the computer mouse within the game. They read the instructions and information provided on the game screen and discussed even minor decisions while laughing at mistakes. When one member performed a wrong action inadvertently, the other pointed it out to reverse the action, showing social learning. They were heard asking, “what is this,” “what to do,” and “what else.” Active communication enhanced information processing, and team members supported each other’s efforts. This resulted in a joint effort to progress, earn more points, level up in the game, and gain rewards. They interacted with other teams as well, to show off a new reward they had earned. The classroom was noisy because of the discussions, and players were having fun.

Only one member of a team was selected for the interview based on the scores. Since they played as a team the score was based on their collaborative efforts in the game. Participant pseudonyms utilized in the following sections: Male high scorer (CMH), Female high scorer (CFH), Male low scorer (CML) and Female low scorer (CFL). The following results are based on the interview data.

Roles, prior knowledge and beliefs. CFL assumed the role of an engineer and CFH a city developer, while CML and CMH did not assume roles. Decision-making was based on prior knowledge and beliefs at first. Later, information from the game helped them change decisions by seeing the impact of their decisions instantly. "First, we made a mistake…we put the coal plant in the residential area then we understood…it will be a problem, so we demolished the thing and we shifted to another area," said CFH. Here discussions helped social learning. Players understood that when an action that was undesirable for the environment was performed, the scores dropped, the green tree icon started changing color, the happy smiley faces became sad, and the other indicators showed negative results. By constantly monitoring these indicators, players were able to discuss and decide whether to continue with an action or rectify their mistakes immediately.

Attitudinal learning. The game contained lots of lessons, said CMH who noted, "When you are building a house, you have to be thinking about the pollution…and about the people." He was referring to the interrelatedness of the environmental systems and how to achieve balance. All participants were affected by the smiley faces that "were much like a human," and they strived to keep the citizens happy. CFL who learned to be "good to nature," said:

> Before…I thought buildings are very nice to see but when I played the game…full of buildings and fewer grasslands…I understood it is not good. I felt sad about the people who are living between many factories in this [city].

Participants learned that construction activities were detrimental "because it would damage nature." CLH and CML were worried about the noise pollution from windmills (renewable energy source), showing empathy for citizens' wellbeing. CFL said:

> I think after playing the game I started thinking about the environment…when I pass a particular place where there is a factory…I feel like…oh the smoke…they are putting all their waste in some river nearby, so I feel like that is bad. It should be changed.

This shows that cognitive learning from the game affected participants, emotionally connecting them to real-life. When the resources reduced, discussions helped "manage power" consumption and "forest cover," said CML indicating social learning.

Pro-environmental behaviors. CFL was already mindful in using less water when there was a shortage. "I switch off lights and started to scold my brother and sister, after playing the game," added CFL. CFH started segregating waste into recyclable and bio-waste actively. When

parents and teachers tried to influence eco-friendly behaviors, CML said he "obeyed to an extent." Now, he does it automatically. CMH, who loved playing games considered the game a challenge, was unaffected by empathy, and his behavior did not change because he was eco-friendly already. Despite playing the game for fun, he learned the significance of "using existing resources judicially" from the game. All four participants became more conscious about their behaviors after playing the game.

Individual game play

Observations. Individual players were totally focused on the game and spoke rarely, and most of them started playing the game before reading the instructions fully. They tried to look at the monitors as they played, showed frustration when their actions did not produce desired results, and tried to reverse their actions. They were serious about playing the roles they assumed. There was no noise in the classroom and interaction was minimal. They understood that wrong actions produced undesirable effects on the environment as was indicated by the monitors, that helped them take correct actions or rectify their mistakes immediately.

Based on the scores generated at the end of the game, interview participants were selected. Participant pseudonyms: Male high scorer (IMH), Female high scorer (IFH), Male low scorer (IML) and Female low scorer (IFL).

Roles, prior knowledge and beliefs. IFH assumed the role of chief of the city while IFL, IML and IMH role-played as citizens. IML disliked playing games but "tried to satisfy the needs of each criteria." Participants based all decisions on the monitors, connected personal experiences and beliefs to the game information and acted. "I just thought that I was one of them...I had two themes…one of society so that it will be better, and…balance," said IMH.

IFH believed that reducing pollution and recycling were the main goals of sustainability before playing the game. Now, she realized the "importance of balance and how nature works." IFL who believed that nature was indestructible before learned that, "non-renewable resources get extinct very fast" and related it to her scores going down as they reduced. They learned that although construction was a symbol of development it was, "not that good for the environment."

Attitudinal learning. IFH as the city chief, did not build factories near houses because she "didn't like it," and believed that construction and other human activities "should not dominate nature." IMH stated, "I didn't want anything to go bad...wanted everything to be perfect. Both

balanced, nature as well as people's happiness." He monitored the smiley face icon continuously and instructed his friends to "look at the people's happiness." IFH learned that as the population increased non-renewable energy sources decreased as shown by monitors. She complained that it was difficult to balance nature, while making people happy was easier. Problem-solving within the game, led them to think about real life. IML reflected, "... if this situation gets worse then how will people live... after the game, I started to think about this." New knowledge from the game produced cognitive and affective learning.

Pro-environmental behaviors. Participants understood the importance of pro-environmental behaviors because they learned that natural resources would deplete fast. After playing the game, IFH tried recycling and started telling friends and family to "switch off the fan, close the water tap." Previously, "I forget to do that, but now behavior is encouraged," said IMH. According to IFL, EnerCities instantly showed the implications of behaviors visually and impactfully that challenged players to strategize. IML who was excited about solving a problem in EnerCities, said:

> Before when disasters are happening around the world…I thought that I couldn't do anything but after playing, I took…a decision like okay something I can do…even if it is a small thing…I could do something good to the Earth.

This is an impactful learning connected to perceived behavioral control (PBC). IML realized the importance of even small actions that every human being can take to make a big difference.

Summary

The attitudinal and behavioral learning were similar for all the participants from both the groups, although they strategized differently. Collaborative players had more fun and learned by discussions with team member while sharing knowledge, performing joint actions, and reflecting on actions together. Individual players were serious about the role they played and relied on their own judgement and knowledge. They immersed themselves in the game by taking first-person perspectives. Each participant mentioned different learning outcomes from the game, showing that several lessons could be incorporated in one game. All participants mentioned the ill-effects of human-caused (anthropogenic) activities. Their mindsets changed about what was more important: fast growth and development, or nature, balance and happiness.

Discussion and Implications

This section explains the derived results using "more integrative strategies" (Plano Clark et al., 2013, p. 223). Irrespective of how EnerCities was played, collaboratively or individually, the attitude towards behavior (ATB), social pressure (SOP) and perceived behavioral control (PBC) had similar influences on pro-environmental behavioural intentions (INT) because the game acted as objects-to-think-with (Holbert & Wilensky, 2019). In this study PBC moderated SOP and ATB producing statistically significant influences on behavioral intentions for all game players combined (Ajzen, 2019). Previous studies using the TPB Model did not feature this moderation that was tested here in an entirely new context. Quantitative analysis showed that PBC is a predictor of behaviour or the perception of a person's ability to perform a given behavior, that depends on factors that may facilitate or impede that behavior (Ajzen, 2019; Cooke et al., 2016). EnerCities made players believe that their perceived control (perceptions of external barriers to behavioral performance) and their self-efficacy or confidence (that one could perform a behavior) increased (Ajzen, 2002) because players were actively engaged in successful pro-environmental behaviors within the game. This was supported by the qualitative data. Before playing EnerCities, even in the presence of social pressure pro-environmental behaviors were not performed. Also, participants believed that they did not have the ability to make a difference. However, after playing they believed that even small actions could have huge implications on the environment. According to Ajzen (2019), PBC produces behavioural intentions that can predict actual behaviors. This indicates that EnerCities was effective in encouraging pro-environmental behaviors among both individual and collaborative game players.

Now, considering the game players and the control group (exposed only to traditional instructional methods of EVS): The influence of beliefs about the likely consequences of the behavior that produces a favorable attitude toward the behavior and influences behavioral intentions was significantly higher for game players compared to the control group. By performing actions and experiencing the consequences within the game (Harker-Schuch et al., 2020; Wu & Huang, 2015) in safe testing zones (De Vries & Knol, 2011; Meya & Eisenack, 2018) players were able to identify correct and wrong behaviors and connect it to real life. This produced a favorable attitude towards pro-environmental behaviors (ATB).

Although some studies using games for knowledge gain were in favor of collaboration in game play, there were some other studies that supported individual game play, based on different

aspects of the game. This exploratory mixed methods study found that attitudinal learning based on the ALI was similar for both individual and collaborative game players. In this study collaboration was outside the virtual space of the game and team members discussed, strategized, and performed actions within the game by taking turns to operate the mouse. The negative aspects noted in literature about collaborative playing of this type did not occur in this study. The disadvantages about individual learning seemed to work in their favor because of their immersion in the game and the empathy it built.

This could be unique for attitudinal learning from games because this study not only measured cognitive knowledge gain, but also affective, behavioral and social learning. In addition, the theory of planned behavior did not show any differences in predicting behavioral intentions between the two groups besides confirming that games were more effective in EVS than traditional methods. This finding is beneficial because implementing teams is cost-effective and less time consuming (Rader et al., 2014). This finding makes it convenient for implementing attitudinal learning games in large classes where technology availability does not match student numbers.

The qualitative phase of this study provided clear insights into why there were no differences in attitudinal learning between collaborative and individual game players, as measured by the surveys. Interviews showed that all game players believed that fast-paced construction activities denoted rapid development, before playing EnerCities. However, EnerCities showed them that loss of green cover, depletion of fossil fuels, and increased construction activities were actually detrimental to the environment and citizens' happiness. Knowledge gain (Bell, 2016; Cuccurullo et al., 2013) and cognitive dissonance (Watson et al., 2018; Festinger, 1975) produced similar cognitive learning for both groups. Both collaborative and individual game players mentioned the ill-effects of building factories close to residences, noise pollution, reduced greenery, and pollution of waterbodies. This shows players' empathy towards the virtual population and also other ecosystem components or the non-human world (Berenguer, 2007; Huckle, 2012; Pahl & Bauer, 2011) indicating affective learning. All players tried to take pro-environmental actions in the game because they saw the consequences immediately not only through their scores but also from other indicators. Irrespective of how EnerCities was played, all participants were affected by sustainability concerns and citizen's happiness, that transferred into their eco-friendly daily behaviors.

However, playing and learning styles were different for collaborative and individual players as revealed by the observation and interview data. Since they did not get feedback from a peer for proposed actions (Hsiao et al., 2014) individual players showed more frustration. This could also be because they could not share their cognitive load (Leahy & Sweller, 2011; Sweller, 2010). They took the perspective of a citizen or the city chief and played the part sincerely. This perspective-taking built empathy and immersed them in the scenario increasing their environmental concerns (Pfattheicher et al., 2015; Schultz, 2000).

Collaborative players felt a sense of security while learning together as novices, while talking and thinking aloud, and hence had more fun (Rader et al., 2014). They strategized their game play easily by sharing complex tasks (Harding et al., 2017; Mullins et al., 2011). Discussions helped social learning (Watson et al., 2018) because sometimes one player missed a cue while operating the mouse. Here, the partner helped in information processing to strategize better. Team members not only observed the partner who was operating the mouse, they were providing verbal cues to guide the action sharing the total working memory resources required for a learning task (Leahy & Sweller, 2011). Both members read the instructions together, watched the monitors, and supported each other's performance, errors, and successes, thereby reducing the cognitive load of each player (Kirschner et al., 2018; Rader et al., 2014; Sweller, 2010).

Generally, even before playing EnerCities, all participants loved "nature," and were aware of pro-environmental behaviors having learned from school, the media, and from parents. However, all players said that eco-friendly behaviors were encouraged by EnerCities because it helped them understand the interrelatedness of nature, humans and other components (Harker-Schuch et al., 2020; Yoon et al., 2016).

Conclusions and Future Research

Changing attitudes and behaviors is not easy, as experienced with the COVID-19 crisis. Health officials are struggling to make people wear masks and maintain social distancing although they are aware of the pandemic. Education does not mean accumulation of knowledge it's about what people do with knowledge and hence attitudinal instruction should be persuasive by giving learners the experience of actions and consequences. This study showed that irrespective of how EnerCities was played, it was more effective in influencing pro-environmental behaviors compared to traditional EVS educational methods. Visually observing a

scenario, taking decisions, performing actions virtually, seeing the results and understanding the consequences, are all possible within a game. This is difficult to execute in traditional EVS instruction. Whether the game was played collaboratively or individually, the attitudinal learning and influence on pro-environmental behaviors was similar. In this study individual and collaborative players mentioned the use of various kinds of actions. Collaborative players relied more on social learning while individual players relied more on perspective taking. However, all of them experienced attitudinal learning from the game covering different aspects, showing that designing a game intentionally would help educators incorporate meaningful lessons into one game. It can be concluded that EnerCities upgraded players' eco-awareness and immersed them in an authentic scenario helping them see the consequences of actions immediately. Going beyond the 3Rs of sustainability - reduce, reuse and recycle - players understood the need to Refuse (the 4th R) more buildings and realize what constituted true development.

Future research could replicate the structural model for TPB and ALI to measure attitudinal learning. Using PLS-SEM for analysis would reveal the influence of individual indicators in surveys. Another strength of this study is the mixed methods approach where the qualitative part enriched this study by providing insights into participants' learning experiences. This study considered only one game and did not compare it with others. More studies using purposefully designed games for EVS are required to corroborate these results. Also, games that are designed for virtual collaboration, that is within the game itself, can be compared with a game like EnerCities.

Another limitation of this study is the lack of a pre/post research design. Assessment of prior attitudes would have provided insights into the extent of attitudinal learning and changes in behavioral intentions after playing the game. To examine the effectiveness of games in producing lasting behaviors, longitudinal studies are required that focuses on actually observing behaviors of participants instead of relying on self-reported behaviors.

Adams et al. (2012) emphasized the need for educational researchers and educational game designers to leverage educational games and their motivating properties to achieve instructional objectives. Considering the growing popularity of computer games, it is wise to leverage such an impactful tool and adapt it as a pedagogical tool to teach young learners about correct environmental attitudes and behaviors and help them understand that:

"The environment is not ours to take or leave, it is ours to make."

-Bhagavad Gita

Declarations

Compliance with Ethical Standards

Conflict of interest – The authors declare that there is no conflict of interest.

Ethics approval – Institutional Review Board (IRB) approval was obtained before conducting this study.

Consent to participate – Informed consent was obtained from all individual participants included in the study.

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Appendix

1. Turning my laptop off whenever I leave my desk is worthwhile.
2. It is necessary to use less water.
3. Recycling waste as much as possible is worthwhile.
4. Switching off the lights when I leave an unoccupied room is good.
5. I am under great pressure to switch off the computer when not using it for some time.
6. People I live with (like parents and other family members) expect me to use less water.
7. My friends recycle waste as much as possible.
8. People around me expect me to switch off the lights when I leave an unoccupied room.
9. I am confident that I can use less water.
10. The decision to switch off my laptop when not in use is purely my decision.
11. Switching off the lights when leaving a room is within my control.
12. Whether I recycle waste is entirely up to me.
13. I intend to switch off my PC when not in use.
14. In the past week I have reduced my water usage.
15. I expect to recycle waste as much as possible.I intend to switch off the lights when not required.
16. I learned new information about the environment.
17. I am more knowledgeable about environmental sustainability.
18. I picked up new ideas about environmental sustainability.
19. I feel excitement about the topic of environmental sustainability.
20. I feel eager to learn more about environmental sustainability.
21. I feel passionate about the environment.
22. My behaviors related to the environment have changed.
23. I did something new related to environmental sustainability.
24. I made changes to my behavior related to environmental sustainability.
25. I do things differently now with respect to environmental sustainability.
26. I talk to others about environmental sustainability.
27. I educate others about environmental sustainability.
28. I am confident discussing about environmental sustainability with others.
29. I connect with other people regarding environmental sustainability.

CHAPTER 4. INFLUENCE OF DIGITAL GAMES ON PRO-ENVIRONMENTAL ATTITUDES AND BEHAVIORS: A MIXED METHODS STUDY IN INDIA USING THE NEW ECOLOGICAL PARADIGM SCALE

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Abstract

Anthropogenic activities cause environmental degradation related problems. However, people fail to perform pro-environmental behaviors because they believe they cannot make a difference or they focus on short-term benefits. Interventions that address specific target groups aimed at breaking barriers and changing behaviors are required. To teach young learners, environmental education using digital games can be a more effective instructional method. This mixed-methods study conducted among high school students in India, examined differences in pro-environmental attitudes and behaviors between students who played a game called EnerCities, and students who did not play that game. Significant differences existed between the two groups considering the unidimensional and multidimensional properties of the New Ecological Paradigm (NEP) scale. Thematic analysis with an inductive approach identified from the interview data, how EnerCities changed participants' environmental attitudes and behaviors. This study finds implications for

implementing games and using the NEP to examine environmental attitudes of high school students in India.

Keywords: digital games, environmental sustainability education, pro-environmental attitudes and behaviors, New Ecological Paradigm scale, mixed-methods study

Introduction

Climate change has caused discernible impacts on animals, plants and their ecosystems that may lead to species extinctions (Root et al., 2003). It is manifested as extreme temperatures and rainfall, decrease in ice and snow and rising sea levels (Karl & Trenberth, 2003), affecting human life and the ecosystem. Despite uncertainties in understanding the complexity of the earth's systems, several research studies point fingers at human-induced changes or activities (anthropogenic) as an important reason (Cordano et al., 2003; Karl & Trenberth, 2003; National research council, 2011; Page & Page, 2014; Rooney et al. 2006; Williamson et al., 2018).

People believe that they cannot make a big difference with this massive global problem (Fielding et al., 2008; Swim et al., 2009), and they tend to focus more on short-term benefits than considering long-term problems (Weber, 2006). Psychologists are looking for innovative ways to increase public engagement by making the issue locally relevant rather than relying on facts and statistics in order to increase the emotional appeal (Williamson et al., 2018; Van der Linden et al., 2015). For interventions to be effective they must be tailored to the target individual or group and address the various barriers that prevent such behaviors (Gardner & Stern, 2002).

Environmental sustainability education (ESE) is one form of intervention (Stevenson, 2007; UNESCO, n.d) and several university degrees are offered on this topic (Bralower et al., 2008; Bryce et al., 2004; Carew & Mitchell, 2007; Guerra, 2016; Segalàs et al., 2009). At the same time, instilling pro-environmental attitudes and behaviors to the "youngest citizens by activating formative and didactic actions" (Cuccurullo et al., 2013, p.113) is very important to prevent future environmental degradation and related catastrophes. Pro-environmental behavior is behavior "that consciously seeks to minimize the negative impact of one's actions on the natural and built world" (Kollmuss & Agyeman, 2002, p. 240).

In K-12 education digital game-based learning (DGBL) can serve as a pedagogical tool in ESE because it is attractive to young learners and can address barriers to pro-environmental behaviors (Gardner & Stern, 2002). Games provide the opportunity to try and test behaviors within

safe zones and perceive the consequences of behaviors immediately (Janakiraman et al., 2018; Ouariachi et al., 2018). In this mixed-methods study, the influence of digital games on producing pro-environmental attitudes was examined in a high school in India using the New Ecological Paradigm scale (NEP; Dunlap et al., 2000). The NEP scale is comprised of 15 statements to measure environmental attitudes and beliefs towards specific environmental issues. It has been used in diverse contexts but not in studying the effectiveness of digital games in India among K-12 students.

ESE is taught as Environmental Studies (EVS) and is a major component in the Indian education system, owing to the need to address the deleterious effects of rapid urbanization, growing industrial activity and climate change. EVS has been taught using traditional methods such as lectures, tests, and projects. In this study, EnerCities, a game designed for EVS, was introduced as an instructional activity. EnerCities helps players visualize how pollution from burning fossil fuels, urban construction, and alterations to land use are some human behaviors that upset environmental balance. By allowing players to test behaviors and examine the consequences immediately, EnerCities indicates the availability of alternate pro-environmental behaviors.

The study sought to identify the differences between the environmental attitudes of two groups of students, those who played EnerCities and students who did not play EnerCities. Interviews with students who played the game revealed perceptions about their prior environmental attitudes and behaviors and how EnerCities influenced them. This study holds implications for using digital games intentionally designed for EVS to influence pro-environmental attitudes and behaviors among K-12 students and also the implementation of NEP among K-12 students in India.

Literature Review

Environmental Attitudes

Environmental degradation may be a slow process but it is as destructive as the violent 2019 Amazonian forest fires (Borunda, 2019) and the Australian bush fires (Daly, 2019). Despite progress in scientific research on environmental degradation's current and future impact on humanity and increased awareness about anthropogenic causes (Bralower et al., 2008; Dunlap et al., 1993) pro-environmental behaviors are not adopted by everyone owing to structural and

psychological barriers (Arbuthnott, 2007; Stern, 2011; Swim et al., 2009; Tucker, 1999). People are in denial or disengaged and unaware that their unsustainable actions are causing environmental degradation and that alternate behavioral options are available (Page & Page, 2014). To overcome psychological barriers to action such as ignorance, uncertainty, mistrust, denial, habit, conflicting goals etc. (Swim et al., 2009), several efforts have been implemented at a large scale by businesses, governments and central agencies (Climate-ADAPT, 2020; Davis, 2019; USAID, n.d.)

For example, when research showed the harm caused to the surface temperatures by anthropogenic emissions of ozone-depleting gases like carbon dioxide and other greenhouse gases like chlorofluorocarbons (CFCs) the Montreal protocol was implemented to control the use of CFCs (Levy, 1997; Montzka et al., 1999; Velders et al., 2007; Williamson et al., 2018). This mitigated the consequences to a large extent and protected the climate (Newman et al., 2009). Similar international agendas are The Paris Agreement (2015), United Nations Climate Summit (2019) and Education 2030, that are striving to bring about such environmental controls to better protect the Earth.

Is it always necessary for the government and central agencies to act? At the micro level what can we as citizens of this earth do? What is under our control? Studies show that simple daily eco-friendly behaviors such as energy conversation can have a huge impact on the environment and climate when enough people adhere to recommended practices (Swim et al., 2009; Williamson et al., 2018).

Although there is a great push for cleaner energy, protection of water bodies, reduction of carbon emissions and carbon footprint, and movement towards renewable energy sources, more intense efforts are required to increase the environmental concern of young learners to make a lasting impact. Young learners have to realize that as future citizens of this earth (Fielding & Head, 2012), they have to be ready to curtail some of their current wants and desires (Nickerson, 2003). They should understand that climate change will affect life today and even more tomorrow, but there are affordable, scalable solutions that can ensure cleaner and more resilient economies (United Nations Climate Summit, 2019).

Since individual attitudes and beliefs are connected to decisions and actions that directly affect the environment, understanding environmental attitudes and behaviors is important (Amburgey & Thoman, 2011). This understanding will help design educational interventions said Pauw and Van Petegem (2012), who emphasize the need for exploring environmental conceptions

of children with respect to different cultures and educational activities, as was attempted in this study.

Digital Games and EVS

Helping young people to learn correct attitudes and behaviors gains importance because studies have shown that age influences pro-environmental attitudes and behaviors (Kafkova, 2019; Wiernik et al., 2013). Digital games are enjoyable and engaging for young learners, (Cuccarollo et al., 2013; Gee, 2008; Prensky, 2006) and can be used as pedagogical tools in EVS. Going beyond providing cognitive knowledge (Bell, 2016; Hungerford & Volk, 1990; Katsaliaki & Mustafee, 2015; Zumbach et al., 2020), games are affective, and can influence behaviors (Cuccurullo et al., 2013; Ouariachi et al., 2019; Yang et al., 2017). The real-world scenarios in games show the negative impacts of wrong decisions and harmful environment-related behaviors immediately, which is not possible in real-life (Arbuthnott, 2009). Digital games provide safe zones to test behaviors, increase awareness of balanced ecosystems, change behaviors regarding environmental protection and recycling and create self-awareness of energy conservation practices through visualizations (Knol & De Vries, 2011; Harker-Schuch et al., 2020; Tan & Biswas, 2007; Wu & Huang, 2015; Yang, Chien, & Liu, 2012;). The situated meaningful contexts in purposefully designed EVS games can ensure systems thinking (Fabricatore & López, 2012; Liarakou et al., 2011; Nordby et al., 2016), in addition to providing meaningful practice before facing such situations in real life (Butler, 1988). Behavioral learning from games could translate into real life as daily behaviors, because according to Ouellette and Wood (1998) well-practiced behaviors tend to become habitual, and the processing that initiates and controls their performance becomes automatic, contributing to intentions that guides behaviors in the future. When such behaviors become habitual, behavioral responses get activated automatically because habits are mentally represented as goal-action links, and intentions may simulate goal-directed automaticity in forming habits (Aarts & Dijksterhui, 2000). Therefore, behaviors in games that are designed to be goal-directed can get transferred to real life and be retained.

New Ecological Paradigm Scale

Being a complex issue, measuring environmental concern is not simple (Jowett et al., 2014), especially when considering K-12 students. The NEP survey (See Appendix A) was designed by Dunlap et al. (2000) to measure the environmental attitudes of people. The NEP scale has been designed to contradict the Dominant Social Paradigm (DSP) that emphasizes abundant resources and progress that may lead to beliefs and attitudes that cause environmental degradation while the new view emphasizes limited natural resources and that humans are altering ecosystems and affecting biodiversity (Pauw & Van Petegem, 2012). The NEP scale used in this study (Dunlap et al., 2000) is the revised version of the New Environmental Paradigm (Dunlap & Van Liere, 1978). The NEP survey instrument considers environmental attitudes and beliefs towards specific environmental issues and human-induced changes and is comprised of items that measure responders' beliefs about the nature of the earth and humanity's relationship with it (Dunlap et al., 2000). Items are related to an understanding of the 1) reality of limits to growth, 2) anti-anthropocentrism, 3) the fragility of nature's balance, 4) rejection of exceptionalism or the "idea that humans are exempt from processes that affect the rest of the natural world (Packer, 2016), and 5) the possibility of an ecocrisis. "From this perspective, people who have pro-NEP attitudes perceive nature as intrinsically valuable and humans as an integral part of the human-nature networks" (Wu, 2012, p.109).

Several studies using the NEP have explored environmental attitudes among adults and in higher education institutions while trying to increase the understanding of what can be measured concerning this complex topic (Dunlap, 2008; Hawcroft & Milfont, 2010; Harraway et al., 2012; Jowett et al., 2014). Studies have confirmed the validity of the NEP scale (Cordano, 2013; Iyanna, 2018; Khan et al., 2012), used the NEP in different contexts (Packer, 2009) and explored the cultural differences in environmental worldviews (Fleury-Bahi et al., 2014; Khan et al., 2012; Wells & Patherick, 2016; Wu, 2012).

A modified NEP scale for children was introduced by Manoli et al. (2007). This scale was used by Pauw and Van Petegem (2012) to investigate the worldview of Belgian, Vietnamese and Zimbabwean children and found that cultural differences existed with respect to environmental attitudes. Evans et al., (2007) designed board games based on the modified NEP scale dimensions in a study involving first and second grade children. A Dutch version was tested by Van Petegem and Blieck (2006) on children aged 13 to 15 years and on children aged 14 to 16 years by Pauw et

al. (2011). Wu (2012) tested the scale among Chinese children. The modified NEP for children aged up to 12 years (Manoli et al., 2007) was not used in this study as the participants were 16 years and above.

Although the NEP was tested for applicability in the Indian context among adults in two major cities (Khan et al., 2012), studies using NEP on K-12 students in India in the context of digital game-based learning in EVS have not been conducted before. Considering the popularity of the NEP and endorsements from many researchers, the NEP scale was chosen as a reliable and valid instrument to measure environmental attitudes of high school students aged 16 to 18 in India, following an educational intervention using a digital game. See Appendix A for the 15 Item Revised NEP Scale. "Agreement with the eight odd-numbered items and disagreement with the seven even-numbered items indicate pro-NEP responses" (Dunlap et al., 2000, p. 433).

Methods

Research Design

This study uses a convergent mixed methods approach where quantitative data and qualitative data were collected one after another on the same day (Creswell & Clark, 2017). One week after one group of students (game group) played the game, quantitative data was collected through a survey from the game group and a control group of students. Qualitative data was collected through interviews from the game group after the surveys were administered (See Figure.10).

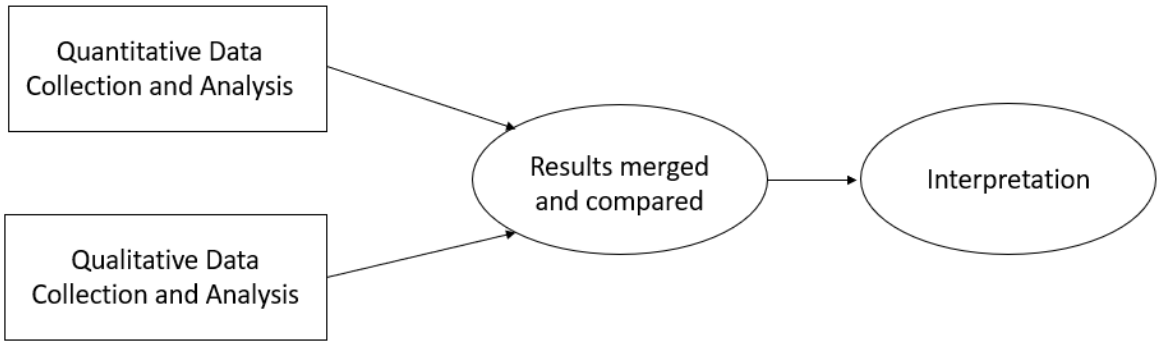

Figure 10. Conceptualization of Mixed-Methods Research Design (Creswell & Plano Clark, 2018)

The following were the research questions:

1. Were there any differences in the environmental attitudes between students who played the EVS game and students who did not play the game based on the New Ecological Paradigm scale?

2. What were the perceptions of participants who played the game regarding their environmental attitudes and behaviors?

Data Collection

Participants

The data was collected from two groups of grade 11 students in a higher secondary school in Kozhikode, an urban city in South India. English is the language of instruction, and the school is affiliated with the Central Board of Secondary Education. There are 65 teachers and approximately 1,500 students belonging to middle- and higher-income families.

For this experimental study, participants included: one group of students (n = 64) who played the EnerCities game either individually or in teams of 2 and a control group (n = 36) that did not play the game. Prior to the study both groups were taught EVS as a separate subject from grades 3 to 5 and then EVS was incorporated with other subjects in higher grades. Hence, the control group was exposed to traditional methods of teaching EVS in prior grades but did not receive the game experience or any additional EVS instruction during this time. EVS encompassed: identification of environmental problems and the interactive processes of nature, care for the environment, prevention of pollution, conservation of energy, and preservation of the environment. IRB permission was obtained before conducting this study.

Context

The game used in this study, EnerCities, is a 3D game created by Qeam with support from University of Twente in The Netherlands to teach about environmental sustainability in the European Union (Knol & DeVries, 2010; Knol & De Vries, 2011). Within the game, players performed activities leading to building a sustainable city with buildings, parks, stadiums, and implementing renewable and non-renewable sources of energy like solar, windmill and

hydroelectric power plants. Players were required to work within fixed resources to maintain green cover, and also maintain the happiness of the citizens in the sustainable city they built.

Quantitative data was collected using the NEP scale and qualitative data through semi-structured interviews. One member of the research team pre-loaded EnerCities on the computers and provided basic instructions. Game group participants were instructed to read the instructions on how to play the game and comprehend the goals. They were given time to get acclimatized with the game mechanics, virtual monitors, scoring system and support features. All participants played the game at least two times. Since there were only 40 computers in the computer lab at the school, students played the game in two groups. After a week, paper-based surveys with statements from the NEP scale were administered to participants from the Game group as well as the Control group at the same time. The NEP includes 15 statements, and respondents are required to report their agreement with these items on a 7-point Likert scale.

For the qualitative phase of the study, eight participants who played the game were interviewed by the researcher to determine what influenced their attitudes before and after the game intervention (Kopnina, 2011) and to understand their learning experiences from the EnerCities game. During the interview, questions related to NEP were not asked directly. Only experiment group (game group) participants were picked for the interview sample because only participants' perceptions based on the game/intervention was required (Plano Clark et al., 2013). All interviews were audio-recorded, transcribed verbatim, and stored on password-protected computers.

Data Analysis

Quantitative data analysis

Dunlap et al. (2000) suggest that it is better to decide the dimensionality of the NEP scale based on the results of individual studies. In this study the unidimensional as well as multidimensional properties of the NEP scale were considered. When the unidimensional properties were considered, Cronbach's alpha coefficient was .81 indicating sufficient scale reliability.

The multidimensional structure of the NEP entails that the 15-items scale is grouped into five interrelated facets: Balance of nature, ecocrisis, antiexemptionalism, limits of growth and

antianthropocentrism. See Table 10 for definitions and reliability values for the five facets based on the study data (Amburgey & Thoman, 2011).

Table 10. Reliability of Items - 5 Facets Multidimensional Property of NEP

Facet	Definition	NEP Items	Cronbach's Alpha
Balance of nature	Beliefs that human activities impact the balance of nature.	3,8,13	.46
Ecocrisis	Beliefs that humans are causing detrimental harm to the physical environment.	5,10,15	.39
Antiexemptionalism	Beliefs that human beings are not exempt from the constraints of nature.	4, 9, 14	.65
Limits to growth	Beliefs that the earth has limited resources.	1, 6, 11	.62
Antianthropocentrism (against human domination)	Beliefs that human beings do not have the right to modify and control the natural environment.	2, 7, 12	.63

Similarly, prior studies conducted both exploratory and confirmatory factor analysis and arrived at four tendencies (Harraway et al., 2012; Jowett et al., 2014; Shephard et al., 2009) to describe the environmental concerns of participants, namely: to conserve, to recycle, to respect animals and plants rights and to be cautious about the future. See Table 11 for definitions and reliability values for the four tendencies based on the study data (Shephard et al., 2009).

Table 11. Reliability of Items - 4 Tendencies Multidimensional Property of NEP

Tendencies	Definition	NEP Items	Cronbach's Alpha
Recycle	Nature provides limited resources	1, 6, 11	.62
Conserve	Nature is susceptible to human interference	3, 5, 9, 10, 13, 15	.68
Rights	Nature does not exist for the benefit of humans	2, 7, 12	.63
Cautious	Humans are subject to the laws of nature	4, 8, 14	.47

Qualitative data analysis

The interview data was analyzed by thematic analysis using an inductive approach to interpret patterns of meaning (Braun & Clarke, 2006) and enabled the research team to approach the data with an open mind. The interview data was read and reviewed to become familiar with it before generating the initial codes. After establishing agreement on the codes among the researchers, categories were defined based on participants' perceptions from the game and the

game features related to them. For example: four codes were identified and grouped under category "Environmental degradation" and two codes for "game mechanics" that enabled participants to learn about environmental degradation. These two categories were combined under the "Human activities" theme. See Table 12 for coding scheme, code frequencies, categories, themes and number of participants (n=x) who discussed the code attribute. This inductive approach was followed by again combing the data for identifying quotes that aligned with the NEP items. This helped understand participants' environmental concerns using the NEP scale.

Table 12. Qualitative Analysis – Coding Scheme

Codes	N	Code Frequency	Categories	Themes
Pollution caused by factories	2	3	Environmental degradation	
Excess construction	5	12		
Fast pace of human activities	6	10		Human activities
Role played by humans	8	12		
Increased awareness of wrong actions	8	15	Game mechanics	
Altering actions on seeing consequences	5	12		
Human ingenuity	2	4	Nature is not indestructible	
Rapid development is not good	5	8		
Tall buildings is not sustained growth	5	7		Prior beliefs and new learning
Sad for people living between factories	2	3		
Loss of green cover - permanent damage	6	9		
Monitoring levels of resources	8	18	Monitors in game	
Instant indication of wrong actions	7	7		
Low scores	6	7	Game challenges	
Game play efficiency	6	6		
Risky game to test strategies	3	3		
Discuss forest management	2	2	Behavior change	
Develop new habits (recycling, save energy, save water)	8	12		Resource depletion and new behaviors
Energy needs keep increasing	6	6	Behaviors in game	
Install more renewable energy sources	7	7		
Take action to boost energy production	7	8		
Reduce building construction	6	6		
Factories emitting dust and smoke	3	4	Transfer to real life	
Water bodies containing waste deposits	3	3		
Humans cannot control/dominate nature	6	7		Connection to real-life
Need to balance with nature	5	5		

Table 12 continued

To gain high scores:			Game scores	
Maintain green cover	6	6		
Balanced construction	6	6		
Keep citizens in game happy	8	8		
Monitor fossil fuels and economy	8	10		

Research Validity

The in-person semi-structured interviews (Merriam & Tisdell, 2016) enhanced and clarified the responses to the NEP survey, ensuring methods triangulation in this mixed methods study (Denzin, 1970). Data triangulation was established by using multiple sources of data (Denzin, 2012; Lincoln & Guba, 1985; Miles & Huberman, 1994) and inter-rater reliability was ensured by multiple rounds of feedback among research team members that also established investigator triangulation (Denzin, 1978). By presenting participant quotes without paraphrasing them, clear and persuasive descriptions have been provided (Erickson, 2012).

Results

This section merges the findings from the quantitative and qualitative parts of this study and compares them (Creswell & Plano Clark, 2018).

Quantitative Findings

Responses to the NEP scale items by the Game (n=64) and Control group (n=36) were evaluated to answer RQ1: Were there any differences in the environmental attitudes between students who played the EVS game and students who did not play the game based on the New Ecological Paradigm scale? It should be noted that whenever participants responded to a statement on the NEP scale they "would likely draw on their cognitive and affective understanding about the statement to anticipate the possible consequences of their relevant behaviors" and hence their attitude as detected by the NEP are linked to behavioral intentions (Harraway et al., 2012).

(1) A one-way ANOVA was performed using SPSS 26 to investigate if any differences existed between the Game and Control groups in environmental attitudes considering the unidimensional properties of the NEP scale. Table 13 provides the mean and standard deviation for the two groups.

Table 13. Descriptive Statistics – Unidimensional Property of NEP

Group	Mean	Std. Deviation	N
Control	2.18	.36064	36
Game	3.76	.33904	64

Result: The EnerCities game produced a statistically significant difference in environmental attitudes of game players, $F(1, 98) = 475.05$, $p < .0005$, partial eta squared = .83.

The result shows that the game impacted the environmental attitudes of game players compared to the control group, considering the unidimensional property of the NEP scale. It should be noted that all participants in the Game and Control groups had studied EVS since grade 3 through traditional methods such as direct instruction, projects and tests. However, playing the game 2-3 times impacted the Game group participants' environmental attitudes significantly.

(2) Next, the multi-dimensional properties of the NEP were considered. MANOVA was performed to investigate the differences between the Game (n=64) and Control groups (n=36), considering the five facets of the NEP scale. Table 14 provides the mean and standard deviation for the two groups.

Table 14. Descriptive Statistics - 5 Facets Multidimensional Property of NEP

	Game	Mean	Std. Deviation	N
Balance of nature	Control	2.50	.66	36
	Game	3.56	.61	64
Ecocrisis	Control	2.35	.45	36
	Game	3.53	.58	64
Antiexceptionalism	Control	2.16	.61	36
	Game	3.80	.67	64
Limits of growth	Control	2.06	.62	36
	Game	3.89	.62	64
Antianthropocentrism	Control	1.84	.56	36
	Game	4.03	.69	64

Results: The EnerCities game produced a statistically significant difference in environmental attitudes of game players when the five facets model of the NEP scale was considered, $F(5, 94) = 106$, $p < .0005$, Wilk's Lambda = .151, partial eta squared = .65.

Univariate ANOVAs were conducted for the five facets individually and significant differences were found between the two groups:

The EnerCities game produced a statistically significant difference in environmental attitudes of game players with respect to the Balance of Nature facet of the NEP scale, $F(1, 98) = 63.6$, $p < .0005$, partial eta squared = .40.

The EnerCities game produced a statistically significant difference in environmental attitudes of game players with respect to the Ecocrisis facet of the NEP scale, $F(1, 98) = 109.85$, $p < .0005$, partial eta squared = .53.

The EnerCities game produced a statistically significant difference in environmental attitudes of game players with respect to the Antiexemptionalism facet of the NEP scale, $F(1, 98) = 142$, $p < .0005$, partial eta squared = .60.

The EnerCities game produced a statistically significant difference in environmental attitudes of game players with respect to the Limits to Growth facet of the NEP scale, $F(1, 98) = 193.5$, $p < .0005$, partial eta squared = .66.

The EnerCities game produced a statistically significant difference in environmental attitudes of game players with respect to the Antianthropocentrism facet of the NEP scale, $F(1, 98) = 259.3$, $p < .0005$, partial eta squared = .73.

(3) Next the differences based on the four tendencies. Table 15 provides the mean and standard deviation for the two groups. MANOVA was performed to investigate the differences between the Game (n=64) and Control group (n=36) considering the four tendencies of the NEP scale.

Table 15. Descriptive Statistics - 4 Tendencies Multidimensional Property of NEP

	Game	Mean	Std. Deviation	N
Recycle	Control	2.06	.62	36
	Game	3.89	.63	64
Conserve	Control	4.62	.80	36
	Game	7.25	.75	64
Rights	Control	1.84	.56	36
	Game	4.03	.70	64
Cautious	Control	2.40	.66	36
	Game	3.64	.70	64

Results: The EnerCities game produced a statistically significant difference in environmental attitudes of game players when the four-tendency model of the NEP scale was considered, $F(4, 95) = 123.73$, $p < .0005$, Wilk's Lambda = .161, partial eta squared = .84.

Univariate ANOVAs were conducted for the four tendencies individually and significant

differences were found between the two groups.

The EnerCities game produced a statistically significant difference in environmental attitudes of game players with respect to the Recycle tendency of the NEP scale, $F(1, 98) = 193.5$, $p < .0005$, partial eta squared = .66.

The EnerCities game had a significant impact on the environmental attitudes of participants with respect to the Conserve tendency of the NEP scale, $F(1, 98) = 269$, $p < .0005$, partial eta squared = .73.

The EnerCities game produced a statistically significant difference in environmental attitudes of game players with respect to Respect Animal and Plant Rights tendency of the NEP scale, $F(1, 98) = 259.3$, $p < .0005$, partial eta squared = .73.

The EnerCities game produced a statistically significant difference in environmental attitudes of game players with respect to the Cautious about the Future tendency of the NEP scale, $F(1, 98) = 76.1$, $p < .0005$, partial eta squared = .44.

The quantitative results from this study found that EnerCities had significantly impacted the environmental attitudes of the game group compared to the control group that did not play EnerCities.

Qualitative Findings

Thematic analysis of the interview data provided insights into Game group participants' perceptions about their environmental attitudes and behaviors before and after playing the game to answer RQ2: What were the perceptions of participants who played the game regarding their environmental attitudes and behaviors?

Prior beliefs and new learning

Participants mentioned how their prior beliefs were altered as a result of playing the game. Although, conserving energy and water and recycling habits were encouraged by adults in their families and school, participants were not inclined to performing those behaviors before playing the game. Also, they thought that nature was indestructible. However, the game showed them that this was not the case by lowering their scores as the levels of resources, green cover and people's happiness diminished. By instantly notifying players of wrong decisions and actions through

scores and monitors that tracked the game play efficiency, players became aware of the consequences of their actions. “Yes, it was a risky game like it challenged us and it wanted to know what strategies we had to take to win the game,” said a participant. This proved very useful in learning new behaviors in the game. The game tested human ingenuity in winning the game that is equivalent to knowing to keep the earth livable. Participants mentioned how they appreciated rapid growth, industrialization and construction of many tall buildings in their city and thought that they were making immense progress. However, after playing the game they realized that the outcome was not beneficial. “I felt sad about the people who are living between many factories in this [game].” They were also disturbed by the loss of green cover each time a construction started in the game.

Human activities

It was evident from the interviews that all participants were now more aware of the major role played by humans in causing irrevocable damage to the environment. They realized that if the present pace of activities continued then the future prospects will be disastrous. They attributed this new learning to the game because it showed the effects of game play decisions and actions immediately. A participant mentioned how she and her partner changed their course of action during the game. She said, “First, we made a mistake…we put the coal plant in the residential area…then we understood that it will be a problem, so we demolished the thing and we shifted to another area.” EnerCities allowed them to change their course of actions and learn in the process.

Resource depletion and new behaviors

The game taught them that the energy needs of humans was only going to increase, and the importance of conserving energy now because resources are “not going to last forever.” Participants worried about the decrease in fossil fuels and the loss of green cover in the game. They mentioned “forest management,” “managing power consumption,” “reducing construction of buildings,” and “installing more solar and wind farms,” as ways to reduce the impact of human activities on environmental degradation. All participants discussed how after playing the game they either developed new habits related to recycling and conservation of energy or increased

practices like saving water, switching off lights and fans, recycling waste and segregating waste at the source.

Connection to real-life

All participants were keen on gaining high scores, similar to student behaviors in tests and exams in traditional forms of instruction. However, strategizing their actions in the game resulted in learning that was transferred to real life. Players were disturbed by the thought of factories emitting dust and smoke that can make life unbearable to people. They noticed water bodies being polluted by waste deposits and felt the urgent need to change. They understood that humans were not meant to rule over the rest of nature and that they will not be able to learn to control nature. One participant said, "…we should make sure that we build things in a balanced way, make sure that we should not dominate nature and we have to balance with nature."

Overall it can be seen that the environmental attitudes and behaviors of game players were significantly changed, after playing the game. They gained new knowledge and were connected emotionally with environmental issues pertaining to nature and human beings. They also understood how their actions would impact the environment by connecting consequences within the game to the real-world and understood that the Earth's resources were limited and humans were constrained in their ability to control nature. Although participants mentioned "nature" multiple times and discussed the effects of human activities on forests and water bodies, they did not specifically mention animals. All participants believed that humans should not dominate over nature and that nature is not robust enough to bear the impacts of rapid industrialization. To connect participants' environmental concerns to the NEP items, specific quotes that addressed the 15 NEP items were identified and tabulated in Table 16. The (R) after some of the NEP items denote that their reversed meaning needs to be considered while analyzing the responses.

Table 16. NEP Scale Items and Participant Quotes

NEP Scale Item	Participant Quotes
1. We are approaching the limit of the number of people the earth can support	"…I also understood that in future…if this situation happens…how will the citizens face it." "…if this situation is going worse…how people will live? So... after the game I started to think about this."
2. Humans have the right to modify the natural environment to suit their needs (R)	"First, we made a mistake…we put the coal plant in the residential area…then we understood that it will be a problem, so we demolished the thing and we shifted to another area."
3. When humans interfere with nature it often produces disastrous consequences	"Before playing the game, I was like this nature will be there for more time and they can't be destroyed easily, but then after playing the game I thought like these non-renewable resources get extinct very fast. And yeah like after non-renewable resource becomes zero…our scores went down."
4. Humans ingenuity will insure that we do NOT make the earth unlivable (R)	"Yes, because it was a risky game like it challenged us and it wanted to know what strategies we had to take to win the game."
5. Humans are severely abusing the environment	"I liked to see many buildings but after playing the game I understand it is not good." "I felt sad about the people who are living between many factories in this [game]."
6. The earth has plenty of natural resources if we just learn how to develop them (R)	"…since population increases their non-renewable resources kept on decreasing…we have to have more energy..."
7. Plants and animals have as much right as humans to exist	"We first played, and we found that resources are going down rapidly, so we understood how to play the game, discussed and managed power consumption and forest management." Before playing the game, I thought buildings are very nice to see but when I play the game, full of buildings and fewer grasslands…I understand it is not good."
8. The balance of nature is strong enough to cope with the impacts of modern industrial nations (R)	"I think after playing the game I started thinking about the environment even when I pass a particular place where there is a factory set up. I feel, oh the smoke…pollution…they are putting all the plastics and waste in water and some river nearby…so I feel like that is bad. It should be changed."

Table 16 continued

9. Despite our special abilities humans are subject to the laws of nature	"We first played, and we found that resources are going down rapidly, so we understood how to play the game, discussed and managed power consumption and forest management."
10. The so-called "ecological crisis" facing humankind has been greatly exaggerated (R)	"…but now I have to be a little bit better because I understood that these will not last forever."
11. The earth is like a spaceship with very limited room and resources	"…there is this much amount of renewable substance…at first I started upgrading technologies like…setting of solar, windmills, etc. But later I came to know that constructing more is…not that good for the environment." "I look at these things [monitors] how much were there, and I took my decisions." "…the only negative feeling was, why did this non-renewable resource keep on decreasing?"
12. Humans were meant to rule over the rest of nature (R)	"…we should make sure that we build things in a balanced way, make sure that we should not dominate nature and we have to balance with nature."
13. The balance of nature is very delicate and easily upset	"When you are building a house. You have to be thinking about the pollution…[and] about people."
14. Humans will eventually learn enough about how nature works to be able to control it (R)	"…we should make sure that we build things in a balanced way, make sure that we should not dominate nature and we have to balance with nature."
15. If things continue on their present course, we will soon experience a major ecological catastrophe	"I understood that more buildings should not be constructed because it would damage something, nature."

Discussion

Wu (2012) stated that interviews about participants' understanding and interpretation of the NEP scale items will provide points of triangulation to identify pro-ecological beliefs more precisely. In this mixed-methods experimental study, the quantitative and qualitative data were integrated to understand how the game encouraged pro-environmental attitudes and behavioral intentions.

Although participants from both groups studied EVS as a subject from grades 3 to 5 and as part of other subjects after that, the game enabled players to realize the harm caused by anthropocentric activities, the limits to nature in sustaining life, abilities of humans in finding solutions to environmental issues and the importance of balance in nature (Dunlap et al., 2000). The game significantly impacted game players environmental attitudes and behaviors when the unidimensional property of the NEP items was considered. Likewise, quantitative findings based on each of the five facets (Amburgey & Thoman, 2011) showed that EnerCities helped players realize that the earth has limited resources, human activities were causing detrimental harm, and humans cannot modify or control nature. This was substantiated by the findings using each of the four tendencies as NEP dimensions (Harraway et al., 2012; Jowett et al., 2014). Players showed higher tendencies towards conservation, recycling, respect towards nature and taking a cautious approach for the future. Game players did not believe that the balance of nature can be easily restored and also realized that humans were responsible and not exempt from what affects nature (Dunlap et al., 2000; Packer, 2016). The findings indicate that similar results are obtained when the NEP is used as a unidimensional scale, or as a multi-dimensional scale with respect to the impact produced by games as educational interventions.

Participants from both groups did not pick extreme options of strongly agree and strongly disagree for any of the NEP items in the survey, a phenomenon reported by Wu (2012) in a study with Chinese children. This could relate to a cultural characteristic of Indian school students who are stepping into adulthood soon, and who are in the process of forming concrete environmental attitudes indicating that it is the right time to influence their attitudes (Kafkova, 2019; Wiernik et al., 2013).

During data collection, participants asked for clarifications about some NEP items. If possible conducting a focus group or conducting a pilot study with a smaller sample at the same research site will be more useful in testing the comprehensibility of the NEP items with that

particular population, as suggested by Kopnina (2011). Based on notes taken by one researcher who was present when participants answered the NEP survey suggestions for modifying few NEP items are provided below.

NEP Scale Item	Suggested Modifications
NEP 4. Human ingenuity will insure that we do NOT make the earth unlivable.	Human cleverness will ensure that we do NOT make the earth unlivable.
NEP 9. Despite our special abilities humans are subject to the laws of nature.	Despite our special abilities humans are controlled by the laws of nature
NEP 10. The so-called "ecological crisis" facing humankind has been greatly exaggerated.	The often-heard term "ecological crisis" that is affecting humankind has been greatly exaggerated.

The qualitative data supported the quantitative findings and provided deeper insights into game play experience, an advantage of mixed methods studies. Although participants' were aware and were expected by their parents and teachers to switch off lights and turn off the water, they were pushed to perform such actions only after playing the game. Even changes in behavioral intentions and talking to others about environmental issues denotes behavioral change (Ballantyne & Packer, 2005). One participant even developed new habits like segregating waste at the source into biowaste and recyclable (Cuccurullo et al., 2013; Wu & Huang, 2015). Participants' learning from the game can be summarized as follows: those who loved seeing tall buildings now preferred more greenery because from the game they learned that buildings eliminated large areas of green cover; those who connected economic growth and development to rapid construction activities changed their minds about what constituted true development; they understood that the earth had limited resources and felt empathy towards ecosystems and people living in other parts of the world and finally they realized that they could contribute, and that even small actions could go a long way in helping the environment. The visualization of consequences immediately following actions within the game enhanced their learning and indicated whether their decisions were wrong or correct. These learning outcomes indicate the achievement of the objectives of EVS and are similar to the findings in prior studies using various games (Cuccurullo et al., 2013; Harker-Schuch et al., 2020; Knol & De Vries, 2011; Tan & Biswas, 2007; Wu & Huang, 2015; Yang et al., 2012).

Using the NEP survey items to examine the interview data provided additional details about game players' perceptions and how EnerCities impacted their environmental attitudes and behaviors (See Table 16). Instant feedback about wrong decisions and actions through scores and monitors helped players track game play efficiency and learn about wrong actions. This proved very useful in learning new behaviors in the game and is connected to NEP4 that tests what humans think about their ingenuity. Players were also disturbed by the loss of green cover each time a construction started in the game connecting to NEP5 and NEP15. The game made players realize that if the present pace of activities continued then the future prospects will be disastrous, relating to NEP1 and NEP3. Altering actions within the game to protect the environment is related to NEP2 that is linked to the realization that humans do not have the right to modify the natural environment to suit their needs. The game taught that resources need to be conserved (NEP6) and that they will not last forever (NEP10) and showed several ways to reduce human impact on the environment (NEP7 and NEP11).

The existence of both an ecological and utilitarian environmental worldview were reported by Pauw & Van Petegem (2012) and Wu (2012) with respect to the NEP. That did not happen in this study with all participants believing that humans should not dominate over nature and they took measures to avoid harmful behaviors within the game. This learning could transfer to real life behaviors and could become habitual (Arts & Dijksterhui, 2000; Ouellette & Wood, 1998).

Implications

Understanding how children develop their environmental attitudes and converting these beliefs to actions is worth researching (Evans et al., 2007). Pauw & Van Petegem, (2012) recommend that children's worldviews and pro-environmental beliefs need to be understood first for developing environmental learning programs to improve their environmental attitudes. In this study all participants had studied EVS from grade three and were influenced by adults. Media exposure ensured that they read a lot about it in newspapers and watched dedicated programs on television. Most local communities also enforced strict regulations about garbage disposal, recycling, rainwater harvesting and so on. Furthermore, the Indian government's awareness campaigns about single-use plastics had gained momentum and at the time of this study plastic bags were hard to find in the market. Hence, cognitive awareness of all participants was similar before this study was conducted. Although prior attitudes were not measured before the digital

game intervention was introduced, this mixed methods study found that EnerCities impacted the environmental attitudes of game players, by comparing them with a Control group.

Does this mean that cognitive awareness did not help them realize that human activities were harmful to the environment and that it is difficult to restore nature's balance, before playing the game? Analyzing the qualitative data provided some insights. Immersion in a near-authentic environment in the game that displayed the consequences of actions immediately proved to be more effective than what happens in real life. This is because results in the form of environmental disasters occur after a long time and children may not be able to connect the cause and the result (Arbuthnott, 2007; Tucker, 1999). Hence EVS should focus on affective and behavioral learning instead of providing facts and figures alone. This can be made possible through digital games.

Games can also serve as support tools to traditional methods of instruction because they make learning fun, engaging and motivating (Gee, 2008), and at the same time help achieve the objectives of EVS. Harraway et al. (2012) point out that it is easy for students to demonstrate knowledge about ecological issues but they could be insensitive to the issue. "Knowledge about the environment and sustainability may be relatively straightforward to assess by conventional examinations and assignments but values, attitudes, and behaviors are not" (Harraway et al., 2012, p.190). They suggest the use of instruments like the NEP to assess environmental attitudes, as was done in this mixed methods study.

Actual learning with respect to topics like EVS, racism, healthy lifestyle, drug abuse, smoking etc. is not accumulation of cognitive knowledge but affective learning and behavioral learning, and digital games can serve as pedagogical tools to achieve wholistic learning.

Conclusions and Limitations

The goals of EVS is to make learners realize that, "Many of today's environmental problems such as global warming, species collapse, and ozone depletion can be attributed to human activity" (Cordano et al., 2003). This can be achieved using games along with minimal instructional support. Despite having studied EVS since elementary school, participants were not aware that human behaviors were causing environmental degradation leading to climate change and related catastrophes. Game players indicated helplessness in dealing with environmental degradation although they tried their best within the game. Their emotional involvement helped them realize the urgent need to address this problem. Not only in K-12 education, games may be

effective as supplementary learning activities in undergraduate education too because even well-designed learning modules did not improve environmental worldview that lasted beyond few semesters, necessitating better educational methods (Rideout, 2005). This needs further investigation.

A pre/post experimental research design was not employed in this study, that would have allowed the research team to examine the differences produced by EnerCities. However, the presence of a control group offset this limitation. Future studies can implement a pre/post experimental design to compare prior attitudes with post-game attitudes to study the influence of different games.

A unique contribution of this study is the use of NEP as a unidimensional scale and as a multi-dimensional scale to compare environmental attitudes when a game was used as an educational intervention. This study showed the suitability of using the NEP scale (Dunlap et al., 2000) with young learners in the age group of 16 to 17 without the need for major modifications as was done for children (Manoli et al., 2007). It can also be concluded that the NEP is a suitable scale for use with high school students in India based on this study. More studies can be conducted in different regions to cover the large and diverse population in India. It is recommended that future researchers conduct a focus group interview before embarking on a larger study to ensure that participants' understanding of the items matched the intention of the item.

Amburgey and Thoman (2011) suggest that the NEP items lack specificity with respect to attitudes and beliefs concerning environmental problems like climate change. EnerCities also did not explicitly demonstrate the connections between human activities and climate change directly although it showed the detrimental effects of wrong behaviors on environmental health. Similar studies using other games and surveys addressing current environmental problems are required.

One interview participant said, "…there are many disasters happening…I thought that I couldn't do anything but after playing [the game] I took a decision…I could do something good to the Earth. Even if a single small contribution…it is a big thing to the Earth, to save the Earth." This is the kind of realization that needs to be instilled in young learners. Although this sentiment was expressed by a single student, it is very likely that he was not the only one to realize it after playing the game.

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Appendix

New Ecological Paradigm Scale

NEP Scale Item
1. We are approaching the limit of the number of people the earth can support
2. Humans have the right to modify the natural environment to suit their needs (R)
3. When humans interfere with nature it often produces disastrous consequences
4. Humans ingenuity will insure that we do NOT make the earth unlivable (R)
5. Humans are severely abusing the environment
6. The earth has plenty of natural resources if we just learn how to develop them (R)
7. Plants and animals have as much right as humans to exist
8. The balance of nature is strong enough to cope with the impacts of modern industrial nations (R)
9. Despite our special abilities humans are subject to the laws of nature
10. The so-called “ecological crisis” facing humankind has been greatly exaggerated (R)
11. The earth is like a spaceship with very limited room and resources
12. Humans were meant to rule over the rest of nature (R)
13. The balance of nature is very delicate and easily upset
14. Humans will eventually learn enough about how nature works to be able to control it (R)
15. If things continue on their present course, we will soon experience a major ecological catastrophe

CHAPTER 5. DISCUSSION AND CONCLUSION

This dissertation comprised three mixed methods research studies that explored the use of Digital Game-Based Learning (DGBL) for attitudinal instruction to teach appropriate attitudes and behaviors regarding environmental sustainability. The first study was conducted in a higher education context in the United States, while the second and third studies were conducted in a K-12 school in India. Irrespective of the venues of the studies, the research goals were the same: to find empirical evidence for the impact of DGBL in environmental sustainability education (ESE) not only in providing cognitive knowledge but also in producing affective and behavioral learning and to understand the features of DGBL that promoted the learning outcomes. In this chapter, a discussion of all three studies is provided in addition to comparing the findings of the three studies and providing implications for how DGBL can be implemented in ESE. As an emerging topic in education, DGBL for attitudinal learning is not very well known. Hence, the author has provided insights from the study that will guide ESE instructors and designers of games that target ESE and other socio-scientific topics. Limitations from the three studies have been identified and directions for future research have been outlined in this chapter.

Summary of Findings

Chapter two describes the first study conducted among undergraduate students in a large mid-western university in the United States. Students in an educational technology course were introduced to DGBL as an educational intervention. As part of their course activities they were required to play a game. This study was conducted as a quasi-experimental study among these students, using an embedded mixed methods approach. Our goal was to examine the influence of attitudinal learning on eco-friendly behavioral intentions of students who played EnerCities, a game designed for ESE. In order to ascertain if behavioral intentions were because of the game, this group's behavioral intentions were compared with another group that played a different game. After one week of game play both groups of participants answered a survey. It was found that for students who played EnerCities, the influence of affective, behavioral and social learning on eco-friendly behavioral intentions was higher. Also, there were no differences in the influence of cognitive knowledge on intentions, indicating that awareness about environmental related issues

alone is not enough to influence behaviors. Furthermore, qualitative data in this study showed that EnerCities produced pro-environmental behavioral intentions by increasing affective, behavioral, and social learning in addition to imparting new knowledge.

During the interviews that were conducted after five weeks, it was found that participants continued their eco-friendly behaviors, they remembered what they learned from the game and their emotions while playing, and still recalled game features that helped them learn. This shows that games can produce long-term retention of attitudinal learning because of the experiences within the game. The findings are important because in previous studies test scores were used to assess cognitive knowledge gain, and observations were used to assess affective and behavioral learning within the game. Prior studies also did not provide a qualitative assessment of learning experiences from the game and the transfer of learning to real-life. In this study, the qualitative phase provided insights into how participants perceived changes in attitudes and behaviors and what features of the game helped them in this process. This helped create a list of game features based on learner experiences and literature that specifically addressthe cognitive, affective, and behavioral components of attitude to produce optimal learning from a game. One interview participant mentioned that she realized that in the real world there was no second chance, unlike in a game, indicating the impact of her learning.

Chapter three describes an embedded mixed methods study that was conducted among high school students in India. Using the Theory of Planned Behavior (TPB; Azjen, 2019) as a theoretical lens, the study explored the effectiveness of DGBL in producing pro-environmental attitudes and behaviors. One group of participants played EnerCities collaboratively in teams of 2 to 3 and another group played individually. It was found that the influence of Attitude Towards Behavior (ATB), Social Pressure (SOP) and Perceived Behavioral Control (PBC) on pro-environmental Behavioral Intentions (INT) were similar for both individual and collaborative game players. Also, irrespective of how the game was played, individually or collaboratively the influence of cognitive, affective, behavioral and social learning as assessed by the Attitudinal Learning Instrument (ALI), on pro-environmental behavioral intentions was similar. These findings indicate that attitudinal learning was similar for game players irrespective of how they played the game, individually or collaboratively. This finding is important because a majority of previous studies focused on cognitive gain have shown that collaborative game play produces better learning than individual game play. Another significant finding is that the influence of ATB, PBC and SOP on INT was

statistically significant for all game players combined (individual and collaborative), considering the mediating effect of PBC on ATB and SOP (Ajzen, 2019). This TPB model has not been tested before, and this study applied the model in a new context: that of a technology-driven intervention. One interview participant mentioned how after playing the game he realized the urgency to save the earth and that his contribution - although small - can help prevent environmental degradation. This supports the above quantitative finding about the mediating effect of PBC on ATB and SOP. When the combined game players data was compared with a control group that did not play EnerCities, game players showed significantly greater ATB highlighting the effectiveness of DGBL in ESE. It should be noted that before the study was conducted all the participants had studied ESE through traditional methods of instruction, hence their knowledge levels were comparable.

The qualitative phase of this study found differences in the way collaborative and individual players strategized their game play. Players also provided insights into game features that helped them learn from the game. Some features helped individual players while some other features helped collaborative players. Individual players took the perspective of the city chief or citizen and played the role sincerely. They were immersed in the game and learned by perspective taking but were frustrated when things went wrong in the game and they were not able to make a decision. Collaborative players were not keen on role playing, they discussed among themselves and took decisions easily and had more fun while playing. They learned more from social learning.

Overall, going beyond the 3Rs of sustainability - reduce, reuse and recycle – game players understood the need to Refuse (the 4th R) and realized what constituted true development. This represented impactful learning from the game.

Chapter four describes the third study conducted in a high school in India. In this convergent mixed methods study, the experimental group of students played EnerCities and the control group students did not play any game. Both groups were taught ESE using traditional methods of instruction from grade 3 to grade 5 and in higher grades as integrated modules within other subjects. The New Ecological Paradigm (NEP; Dunlap et al., 2000) scale consisting of 15 items was administered one week after game play to test the environmental attitudes of the two groups of students. This was followed by interviews. The study showed significantly higher environmental attitudes among game players compared to students who did not play the game, considering the unidimensional (Dunlap et al., 2000) as well as multidimensional (Amburgey and

Thoman, 2011; Harraway et al., 2012; Jowett et al., 2014) properties of the NEP. This is an important finding because previously there were differences among researchers about how to implement the NEP. The qualitative phase of the study showed that despite having studied ESE since elementary school, participants were not aware that human behaviors were causing environmental degradation leading to climate change and related catastrophes. Game players indicated helplessness in dealing with environmental degradation although they tried their best within the game. Their emotional involvement in the game helped them realize the urgent need to address this problem. Another significant finding of this study is that the NEP scale can be used with young learners in the age group of 16 to 17 without the need for major modifications as was done for children in the age group of 12 to 15 (Manoli et al., 2007). It can also be concluded that the NEP is a suitable scale for use with high school students in India based on this study. Few suggestions for rewording some NEP items have been provided.

Implications for game designers and ESE instructors

This dissertation study found that games are strong alternatives to traditional forms of education for changing attitudes because they allow learners to test their behaviors and see the consequences of harmful behaviors on the environment immediately, facilitating retention of learning and behaviors. All three studies provided insights into why DGBL could be integrated in ESE, and how to design and implement DGBL for ESE to make it effective for different kinds of environments, and audiences. Furthermore, the studies showed that DGBL was effective in producing pro-environmental attitudes and behaviors among learners in K-12 as well as in undergraduate education. The implications from this dissertation study, as outlined below, can be applied in the design and implementation of DGBL for instruction in other socio-scientific topics like racism, child abuse, health, and smoking as well.

Effectiveness of DGBL in ESE

The goals of ESE is to make learners realize that human caused or anthropocentric activities are directly connected to environmental degradation and problems like global warming, species collapse, and ozone depletion (Cordano et al., 2003). This can be achieved using games along with minimal instructional support. Games designed for subjects like Math, Science, language etc. are

focused on cognitive knowledge gain only. However, attitudinal learning encompasses cognitive, affective, and behavioral learning. Hence, when exploring the effectiveness of games for ESE a holistic approach to learning has to be considered. The three studies informed how EnerCities, a game designed intentionally for ESE, addressed the three components of attitudinal learning and also social learning. This will help instructors gain confidence in implementing DGBL for ESE as an effective activity and also help them assess environmental attitudes.

DGBL offers two modes of interaction: learning for playing and learning from playing (Hong et al., 2013) and is useful in providing cognitive knowledge (Bell, 2016) also because games increase players' understanding of sustainability issues by providing immersive environments (Katsaliaki & Mustafee, 2015). Here are some recommendations for how instructors can support student learning based on literature and findings from the three studies:

a.) Use games that are designed to provide instruction that will keep players on track and focused on the learning goals because appropriate prompts in sustainability related games help enhance cognition and metacognition of players. All the three studies in this dissertation and prior studies (Cuccurullo et al., 2013; Knol & De Vries, 2011; Zumbach et al., 2020) found that prompts given by a virtual agent or other pop-up boxes support attitudinal learning. In EnerCities, such prompts helped provide new knowledge and informed players about correct and wrong decisions by giving immediate feedback.

b.) Allow learners to think and learn about the interrelationship between events seen within the game. The indicators in EnerCities showed the amount of available resources that depended on player choices. For example when new buildings were built income increased, however green cover (tree icon) and people's happiness (smiley face) were reduced. This portrayed the interconnectivity of the environment as was seen in other studies (Fabricatore & López, 2012; Harker-Schuch et al., 2020; Liarakou et al., 2011; Yoon et al., 2017). Studies one and two discussed this aspect of games.

c.) Select games where game mechanics focus on empathy building. All three studies that form this dissertation and previous studies (Ninaus et al., 2019; Tan & Biswas, 2007; Yang et al., 2012) have shown the power of emotional involvement/engagement with game elements that produce attitudinal learning. Decreasing people's happiness and green cover in EnerCities emotionally involved players.

d.) Allow learners to play the selected game in teams of 2 to 3, or individually. Although learners strategize game play differently, their attitudinal learning outcomes are similar, as shown in Study 2. Teachers need not worry about assigning one computer per student because playing in teams also produces similar attitudinal learning. This is helpful in schools where the number of computers is low compared to the number of students. Comparison between individual and team players while playing an attitudinal learning game has not been examined before. Hence this is an impactful finding from this study. It should be noted that prior studies have compared individual and collaborative game play using games designed for other subjects like Math, language literacy, social studies and science topics, providing mixed results. Some studies supported collaborative game play (Hsiao et al., 2014; Prez & Guzman-Duque, 2014), while some supported individual game play (Plass et al., 2013; Stanton & Neale, 2003) and some did not show any difference in learning outcomes (Chen et al., 2015; van der Meij et al., 2011).

e.) Enable learners to examine the consequences of actions in real-time through DGBL environments. Games provide situated and meaningful contexts (Knol & De Vries, 2011; Liarakou et al., 2011; Wu & Huang, 2015) using the power of visualizations (Harker-Schuch et al., 2020) and a discovery learning environment (Tan & Biswas, 2007). Games like EnerCities are designed to show game outcomes instantly following actions as was reported in all three studies (Cuccurullo et al., 2013; De Vries & Knol, 2011; Wu & Huang, 2015). Instructors can use this instant and accurate feedback to demonstrate real-life consequences of behaviors because in real-life the effects are visible only when they become disastrous and not quickly restorable (Arbuthnott, 2007).

f.) Most games are based on an interesting narrative or story (Dillon, 2005). Instructors need to engage learners with these stories to connect players to the plot and the game so that players feel the tension or climax (Jull, 2001) that may create empathy. In structured situations like in classrooms, empathy games allow player to take a different perspective and learn from the virtual experience. Johnson (2019, November) discuses several empathy games and how they could be used in classrooms for instruction regarding racism, gender and sexuality, poverty and others. Prior studies have explored how games can be effective in producing empathy among players (Belman & Flanagan, 2010; Greitemeyer et al., 2010; Yang et al., 2012; Tan & Biswas, 2007). Although EnerCities did not have a storyline the

instructions page explained the scenario. Players were required to build a sustainable city with respect to green cover, energy use, fossil fuels, economy and buildings for residences, recreation, offices, markets etc. while also keeping the virtual population happy. A realistic problem that was faced on earth was presented and the visual graphics depicted the changes that happened as the player manipulated the scenario. This description was not adventure-based or fantasy-based but was able to build empathy. All players were emotionally engaged with the city and the people living there, connecting the scenario to real-life situations.

This and previous studies have shown that behavioral learning from games could translate into real life as daily behaviors, because according to Ouellette and Wood (1998) games offer practice with certain behaviors that may guide behavioral intentions in the future. Even talking about pro-environmental behaviors with others is considered a behavioral change (Ballantyne & Packer, 2005) that was exhibited by participants as social learning in this dissertation study. When such behaviors become habitual, behavioral intentions may simulate goal-directed automaticity in forming habits (Aarts & Dijksterhui, 2000). Therefore, behaviors in games that are designed to be goal-directed can be transferred to real life and retained. Hence games will help achieve the ultimate goal of instructors, that is produce attitudinal and behavioral changes among their students.

It is easy for students to demonstrate knowledge about ecological issues but they could be insensitive to the issue. Also, it is relatively straightforward to assess knowledge about environmental sustainability using conventional examinations and assignments but it is not easy to assess values, attitudes, and behaviors (Harraway et al., 2012, p.190). This study showed that the New Ecological Paradigm (NEP) scale can be used to measure environmental attitudes of high school students with respect to various components as defined by the properties of the NEP scale.

Prior knowledge about environmental sustainability and the effects of anthropocentric activities did not encourage participants in the three dissertation studies to perform only pro-environmental behaviors. However, immersion in a near-authentic environment in EnerCities that displayed the consequences of actions immediately was more affective. Results in the form of environmental disasters in real life occur after a long time, and learners may not be able to connect the cause and the result (Arbuthnott, 2007; Tucker, 1999). Hence ESE becomes more effective when it focuses on affective and behavioral learning also instead of only cognitive knowledge.

This can be made possible through digital games that can be used as support tools to traditional methods of instruction.

In addition to the implications based on the study findings, the process of conducting the studies and the experience gained by implementing EnerCities in the high school and undergraduate class have helped provide more implications for instructors. They are as follows:

a.) Instructors need to be aware of the availability of digital games for teaching various subjects. There are numerous websites with online games for attitudinal learning including 2D and 3D games. EnerCities used in the dissertation studies was a standalone 3D game that was manually loaded on students' computers from a flash drive. Although online games are easier to access, instructors can look for offline games. Most K-12 schools, especially in emerging economies like India and in some cases in developed nations, may not deploy uninterrupted internet connectivity to computers accessed by students. Also, internet connectivity at home may be a problem with concerns about affordability, cyber safety and parental permission.

b.) Instructors need to play the game at least once before implementing it in their classes to be familiar with the storyline, game mechanics, levels in the game, and few winning strategies. This is exactly like preparing for a traditional class. However, implementing a game will save instructors a lot of time in explaining real life dynamics.

c.) Instructors have to select games that align with the learning objectives of the course and should not try to derive objectives from the games (Watson et al., 2011) to avoid ambiguity. The EnerCities game used in the dissertation studies aligned with 90% of the course objectives. It was available for free upon request from the creators of the game. Instructors can launch an internet search for games that align with their course objectives and try to procure it in downloadable formats. Games for sustainability education and other topics are freely available online too.

d.) Providing an overview of game goals, and why students are expected to play the game before game play starts, and a debrief session after students play a game will enable instructors to make sure that attitudinal learning was successful. This will be especially useful when a game is played individually. While debriefing, instructors are providing an opportunity for social learning among students and between students and instructor. This type of facilitation is a powerful instructional strategy.

The above recommendations for the use of DGBL in ESE instruction based on this dissertation study are applicable to other attitudinal learning topics as well. Going a step forward, if students are actively mentored about their behaviors in the real world by adults at home and teachers then it will be even more effective. For example using Quest Atlantis a game that adopted a socially responsive design, researchers found that when players performed real-world, socially and academically meaningful activities after playing a digital game, their social awareness, commitment to communities, and learning was improved (Barab et al., 2005). Quest Atlantis included EcoWorld quests that promoted learning about environmental sustainability.

Game Features that Facilitate Attitudinal and Behavioral Learning

Implications based on the study findings are enumerated below with respect to game features that facilitated attitudinal learning. Game mechanics or features make a game fun, engaging, challenging and attractive to young people and plays an important role in the learning process. The game features usually seen in recreational games are integrated into games designed for subjects like language, Science and Math with additional knowledge prompts. In the case of attitudinal learning games more specifically designed features that target attitudes are also necessary besides the usual features. These implications will be beneficial for designers of games targeting attitudinal change.

First of all, attitudinal learning game designers should have knowledge of instructional design principles and learning theories (Plass et al., 2015). Here unlike recreational games, motivation to win is not the only goal. Winning means several other things and is not focused on one player or a team reaching the last level as in recreational games, for example reaching the top of a mountain or a treasure chest. Similarly winning does not mean answering all the questions correctly while crossing an obstacle course or playing a matching game, like in educational games. In attitudinal learning games, winning may not depend on the levels reached, the numeric score, or time spent on the game but it refers to actual changes in attitudes and behaviors. This dissertation showed that the absence of seductive features that may cause cognitive overload and distract from the attitudinal learning (Adams et al., 2011; Mayer, 2005; Sweller, 2010) were not featured in EnerCities. Hence, instructional designers working on attitudinal learning games must understand the cognitive theory of multimedia learning.

Based on our previous work (Janakiraman, et al., 2018), a literature review on DGBL for attitudinal learning in ESE, and the dissertation studies, a list of game features that influenced cognitive, affective and behavioral learning was created as shown below in Table 17.

Table 17. Attitudinal learning and game features

Cognitive Learning	Affective Learning	Behavioral Learning
Real-world scenarios	Situated learning	Safe, simulated conditions
Systems thinking	Immersive environments	Active engagement
Problem solving	Empathy creation	Live action & practice
Discovery learning	Happiness monitor	Test behaviors
Spirit of inquiry	Narrative or storyline	Engaging
Active engagement		Repetition
Visualizations		Rewards for motivation
Repetition		
Virtual agent		
Visual prompts		

The above table does not include social learning because EnerCities was not designed as a multi-player, multi-modal type of game. Social learning within the game was not supported, however in study 2 learning from playing the game individually and in teams of two was examined. Findings showed that attitudinal learning was similar for all players irrespective of how the game was played. Interviews in all the studies indicated that after playing EnerCities, participants talked to others about environmental sustainability and that they were confident to connect to others about the topic. Furthermore, learning can occur when a teacher introduces the goals of the game and again when the teacher debriefs after the game is played. Hence, facilitation by teachers when a game is implemented is a very important criteria that solidifies attitudinal learning among young learners.

In EnerCities, there were several monitors, a scoring system, a level up bar, three icons on environmentally friendly building upgrades and a virtual instructor/agent that guided game play. The monitors revealed the availability of fossil fuels, electric power, financial resources for power

generation, green cover, options for buildings and most importantly an emoji that showed happiness levels of citizens in the city that was being built by the player. See Figure.

Figure 11. Screenshot of game in progress

Also, the virtual instructor or agent gave useful tips about how to use the available resources and balance game play. These prompts encouraged players to consult the game monitors before taking any action and helped them advance. The dissertation studies showed how useful each of these features were in attaining success in the game and how these features also helped in attitudinal learning.

For example, the emojis and the tree (green cover) icon increased the emotional involvement of all players in all the studies. Players described how the sad emojis and reddening of the tree icon pushed them to stop certain actions, rethink strategies and take alternate actions even if that meant losing some points. They realized the effects of anthropocentric activities instantly. This shows that game mechanics should include features that get players involved emotionally to learn attitudes and behaviors.

Multiple avenues for performing the same action should be incorporated because it gives more practice with behaviors in the game that has the power to produce attitudinal learning. EnerCities allowed players to level up and each time the game offered better types of renewable

energy options that could be used to upgrade multi-story buildings. Players were able to learn about alternate energy options, scale and scope of implementation, locations suitable for renewable energy generation, population dynamics and how buildings can be made energy efficient while constructing them.

The game also showed them that fossil fuels were necessary in a balanced economy and that they should not become extinct. Actions and consequences revealed the inter-connected nature of the environment. Learners found that an action in one part of the game produced a change in another. Seeing the harmful consequences helped them to alter their behaviors. Some players actually went back in the game and avoided the harmful action thereby experimented with their actions. This helped them realize that in real-life this change in action is not possible and once environmental degradation sets in, it will take decades to rectify the effects. Such features provided cognitive knowledge, affected them emotionally and helped them change behaviors. The scoring system kept them on track as well. All these helped them learn the importance of balancing with nature by following the visual prompts provided by the monitors and the virtual agent. Participants revealed how the behaviors within the game encouraged them to perform pro-environmental behaviors more readily in their daily lives.

Hence, based on the outcomes of the three studies and literature, games designed for attitudinal learning:

1. must provide multiple lessons within the same game incorporated in a storyline
2. provide prompts through a virtual agent to improve learning and performance in the game
3. provide several opportunities to repeat an action but with added variety to engage players
4. incorporate several monitors that indicate levels of resources and other parameters
5. provide dedicated monitors to show improvement, e.g. emoji that showed happiness, tree icon that showed environmental restoration/degradation
6. reveal reactions of every action taken to ensure systems thinking
7. avoid seductive features that cause cognitive overload, e.g. flashing icons, bright colors
8. make the game look realistic to provide the real-life connection
9. offer rewards in the form of better tools, e.g. upgraded renewable energy options

10. create game mechanics that don't instruct directly but provides a discovery learning environment to make learners take ownership for their learning.

All the above features will help promote attitudinal learning as was revealed by the studies. It is recommended that instructional designers incorporate the above elements when designing games for attitude change.

Limitations and Future Research

Limitations were identified in all the three studies. These can be attributed to the nature of the studies that focused on attitudinal learning and not just knowledge gain. Quizzes and tests could not be used and hence we relied on self-reported responses to survey questions and interviews. There was no way we could observe the behaviors of the game players; however, in the second study the teachers who were present during the study were contacted after 4 months. The teachers reported seeing some students who participated in the study switching off fans when leaving the classroom. However, it is very difficult to attribute this to the game and hence were not reported in the study.

In study one, data collection happened after five weeks of game play. Interviews revealed several instances that showed that game players retained their attitudinal learning, practiced new behaviors and had a good memory about the game features that enabled the learning. This indicates retention of learning and actual changes to behaviors that can be attributed to the game. This is similar to results obtained from quizzes that assess knowledge of material learned the previous day or few hours prior. Only in rare occasions are quizzes and exams implemented without previous announcement. Future research can involve a longitudinal study over several months if confounding variables can be controlled for. However, that is very difficult given the increased media coverage about environmental issues. Also, researchers should consider the fact that attitudinal learning is not a one-time change or for few years. It should be life-long.

Another factor to consider is the data collection instrument and analysis methods that could be used for assessing attitudinal learning and behavioral change. The first and second study employed the Attitudinal Learning Instrument (ALI) to assess cognitive, affective, behavioral and social learning. Each of the survey components had multiple indicators or survey items. The second study used the Theory of Planned Behavior (TPB) as a lens to study attitude towards the

behavior, social pressure and perceived behavioral control and behavioral intentions. Multiple indicators were present for each component in TPB also. Instead of considering averages Structural Equation Modeling (SEM) was used in both cases. SEM is a multivariate statistical analysis technique and is a combination of factor analysis and multiple regression analysis that helps analyze structural relationships between measured variables and latent constructs. In these studies, SEM was used for the first time with ALI and a structural model was created to measure attitudinal learning after one week and after five weeks. This method was perfect for the study goals because it estimated the multiple and interrelated dependence in a single analysis. It is recommended that future researchers employ the structural models created in study one and study two to examine attitudinal learning and behavioral intentions over longer periods of time.

The third study used the NEP scale that assessed environmental attitudes. This scale provided deep insights into learner perceptions about 15 different items related to the environment. Study three also used the NEP to examine the interview data to identify quotes that discussed different elements of environmental attitudes. Future researchers could analyze data using either the unidimensional or the multidimensional properties of the NEP because similar results were derived in this study. However, this could be the case only with technology-based educational interventions or only with games. Also, studies with children aged 16 to 18 and studies conducted in India could use the NEP without any major modifications. However, it is recommended that researchers consider doing a pilot test in the same venue possibly with a smaller sample (who will not participate in the actual study). Researchers could consider using simpler terms for some NEP items as listed in the third study. Together the ALI and NEP could be used in future studies to get a deep and holistic understanding of how games produced attitudinal learning.

All three studies did not employ a pre- and post-test research design because we did not want to prime participants about the research goals and because ALI may not be suitable for a pre-post implementation since it was designed to only assess learning after an educational intervention. This was a major limitation in all studies. Future research could implement the NEP before the game intervention to find out prior environmental attitudes and use the ALI as a post-game survey to assess the learning. This will make analysis difficult however and will not be a true pre-post experimental design.

The qualitative data was a great addition that helped override the lack of data about prior environmental attitudes in these studies. Interviews revealed prior attitudes and changes in attitude.

Again, only a small fraction of all game players were interviewed. Future researchers could consider including a text response question about prior environmental attitudes in the post-surveys or consider administering a pre-survey several months before the game intervention. Controlling for prior attitudes and confounding variables in attitudinal learning regarding environmental sustainability will always be difficult given the traction that this topic is receiving presently.

In all three dissertation studies, a control group was used that received an intervention different from the experimental groups that helped offset the limitation to some extent. Hence it can be concluded that the control group (with very similar characteristics as that of the experimental group with respect to prior knowledge and attitudes) will help compare learning, attitudes and behaviors before game play and after game play.

With respect to EnerCities, the game used in all the three studies, one major limitation was identified. EnerCities did not directly demonstrate the connections between human activities and climate change; although, it showed the detrimental effects of wrong behaviors on environmental health. Similarly, Amburgey and Thoman (2011) pointed out that the NEP items lack specificity with respect to attitudes and beliefs concerning environmental problems like climate change. Future studies should use other games designed for ESE and use other survey instruments that address current environmental problems. Games that are designed to teach real mindful daily behaviors, like reducing energy use and water consumption, and games connected to other aspects of sustainability such as packaging, travel, and food waste, will provide more insights into how successful games are in producing pro-environmental attitudes and behaviors.

Future research using a mixed methods approach and replicating the structural model for TPB and ALI to measure attitudinal learning can be conducted in a pre-post research design with a bigger sample size. Using PLS-SEM software would further reveal the influence of individual indicators of surveys. The qualitative part of the study enriched these studies by providing insights into participants' learning experiences. Deep insights about the attitude towards pro-environmental behaviors and control beliefs that inhibited or encouraged pro-environmental behaviors were gleaned from the studies. Similar studies on other socio-scientific topics concerning racism, behaviors during pandemics, health, food, drug abuse, smoking, road safety etc. are essential to establish the effectiveness of digital games in attitudinal learning.

Conclusion

All three studies in this dissertation were focused on the effectiveness of digital games in environmental sustainability education (ESE). Adams et al. (2012) emphasized the need for educational researchers and educational game designers to leverage educational games and their motivating properties to achieve instructional objectives. The finding from the three studies provided evidences for the use of DGBL to support traditional forms of instruction. DGBL is effective for attitudinal learning because it offers a fun, engaging, motivating, challenging, immersive and attractive platform that allows players to test their behaviors and see the consequences of harmful behaviors on the environment immediately, thereby facilitating retention of learning and behaviors. (Chen, et al., 2019; Gee, 2007; Harker-Schuch et al., 2020; Knol & DeVries, 2011; Prensky, 2003; Troussas et al., 2019). Researchers have stressed the importance of studying long-term learning from games (Cheng & Annetta, 2012; Harker-Schuch et al., 2020). Qualitative data from all three studies showed that attitudinal learning from games have the potential to be retained longer to some extent because of the experiences within the game.

EnerCities upgraded existing eco-awareness and immersed players in a scenario that they were responsible for and helped them see the consequences of actions immediately. Visually observing a scenario, taking decisions, performing actions virtually, seeing the results and strategizing based on monitors, and understanding the consequences are all possible within a game and difficult to execute in traditional ESE instruction. Going beyond the 3Rs of sustainability - reduce, reuse and recycle - players understood the need to Refuse (the 4th R) more and realize what constituted true development. This is an impactful learning from the game.

Players' feelings of empathy for the human and non-human world were transferred to real-life behavioral intentions that were displayed a week after game play indicating that it could lead to actual behaviors (Aarts & Dijksterhui, 2000; Ajzen, 2019; Ouellette & Wood, 1998).

Considering the growing popularity of computer games, it is wise to leverage DGBL as a persuasive pedagogical tool because it provides opportunities to evaluate the impact of decisions in a highly engaged environment that can push young learners towards correct attitudes and behaviors. Although there are concerns about using digital games in education, this study endorses the view that games can be used for attitudinal learning. This aligns with what Gee (2008) said about the need for knowledge to be provided as an experience and to be situated in scenarios that help learners develop situated understandings. One interview participant said, "…there are many

disasters happening…I thought that I couldn't do anything but after playing [the game] I took a decision…I could do something good to the Earth. Even if a single small contribution…it is a big thing to the Earth, to save the Earth." This is the kind of realization that needs to be instilled in young learners. Although this sentiment was expressed by a single student, it is very likely that he was not the only one to realize it after playing the game. This dissertation concludes that games can be persuasive pedagogical tools for attitudinal and behavioral learning to help young learners understand that:

"The environment is not ours to take or leave, it is ours to make."

-Bhagavad Gita

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