



# 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 · Environmental sustainability · Pro-environmental behaviors

Melting polar ice, temperature departures, and climate change across the globe (Brinkmann 2020; Osiobe 2020; Vorkinn and 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 and Trenberth 2003; Meya and Eisenack 2018). Also, pandemics like COVID-19 are due to zoonotic transmission of diseases from animals to humans caused by alteration to natural habitats (UNEP 2020). Even 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 and Thoman 2012; Jowett et al. 2014) and have prescribed education for sustainable development as a solution (Meya and 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 and Head 2012). Education should promote mindfulness (Wang et al. 2019), be persuasive in order to change attitudes and behaviors (Griset 2010; Sinatra et al. 2012), and be interactive (Meya and 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 (Janakiraman et al. 2020; Harker-Schuch et al. 2020; Wu and 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 and Wilensky 2019).

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Many prior studies using educational games showed that collaborative efforts are more beneficial in learning compared to individual efforts (Hsiao et al. 2014; Prez and Guzmán-Duque 2014), while some studies contradict that (Plass et al. 2013; 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 behavior (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. However, educators do not promote the use of games because they think it is time consuming and that there are not enough devices for all students.

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 theory of planned behavior and the attitudinal learning instrument. 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 analyze 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 et al. 1992) and is comprised of three components (Kamradt and 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 and 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 and Volk 1990), and develop empathy (Berenguer 2007; Pfattheicher et al. 2016), by perspective taking (Pahl and Bauer 2013). EVS should encourage pro-environmental actions irrespective of barriers and constraints (Arbuthnott 2008; 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 (Habgood and 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 (Janakiraman et al. 2020; Fabricatore and López 2012; Liarakou et al. 2012; Nordby et al. 2016; Yoon et al. 2017). Games increase players' knowledge of sustainability issues and sustainable development strategies (Janakiraman et al. 2018; Katsaliaki and Mustafee 2015) by making them perform actions that may be inconsistent with their existing attitude and slightly consistent with the target attitude (Kamradt and 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 and Huang 2015). These realistic scenarios give meaningful practice before facing the real action influencing pro-environmental attitudes and behaviors (Butler 1988; Knol and De Vries 2011; Tan and 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). The cognitive load or the total working memory resources that is required to carry out a learning task (Leahy and Sweller 2011; Sweller 2010), is shared among team members while processing complex material, improving information processing and understanding (Kirschner et al. 2018). Räder 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: (1) 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 and Guzmán-Duque 2014). (2) 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 and 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 and Guzmán-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 showed no difference in engagement, motivation, and learning outcomes between collaborative and individual players (Chen et al. 2015; van der Meij et al. 2011). Interestingly collaboration seemed to help only when scripted roles and tasks were given to the collaborative players

(Hämäläinen et al. 2008; Weinberger et al. 2005). Also, collaboration in games is inhibited by extreme domination of one member (Stanton and Neale 2003) and conflicts occurred due to mismatch in personalities and cultural backgrounds, necessitating a positive group dynamic (Chen et al. 2015). 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 environmental studies. This mixed methods study strives to close that gap.

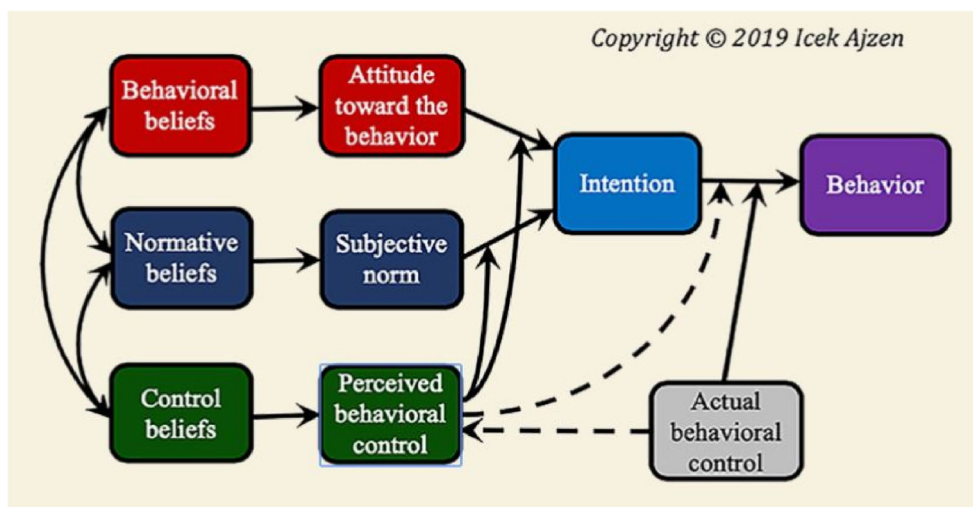
### Theory of Planned Behavior (TPB)

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 attitudes and social pressure 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 as shown in Fig. 1.

### 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

Fig. 1 TPB Model (Ajzen 2019)



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 goals 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 in 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

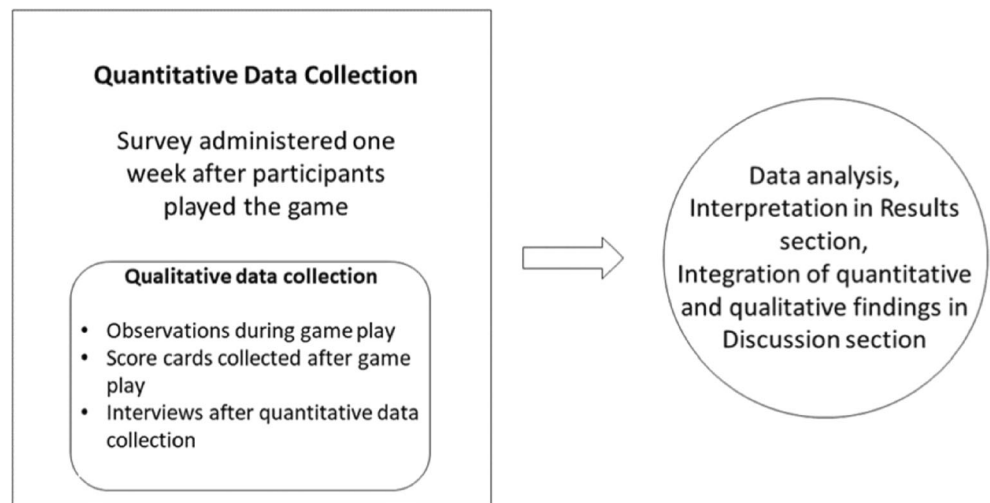
### Research Design

An Embedded Mixed Methods research design (Creswell and Clark 2017) comprising two phases was employed in this exploratory study: quantitative data was collected first, and qualitative data was collected next as shown in Fig. 2. 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.

### 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 (2) 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 and 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 131 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.

**Fig. 2** Mixed-Methods research design



## Game Context

According to van der Meij et al. (2011) it is important for instructors 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 the University of Twente and partners, to be implemented for EVS in European schools (Knol and De Vries 2010; Knol and De Vries 2011). EnerCities was played on computers pre-loaded with the game in this study. Students were encouraged to play 2–3 times. Total time provided was 50 min.

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 and 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 3 shows an instance of game play with indicators and icons. Figure 3.

## Data Collection and Analysis

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

**Fig. 3** EnerCities game screen showing indicators



learning using a 5-point scale. See Appendix 1 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 Fig. 4). Using the SmartPLS 3.0 software package PLS-SEM bootstrap was executed taking 2000 subsamples to examine if the structural model fits the data.

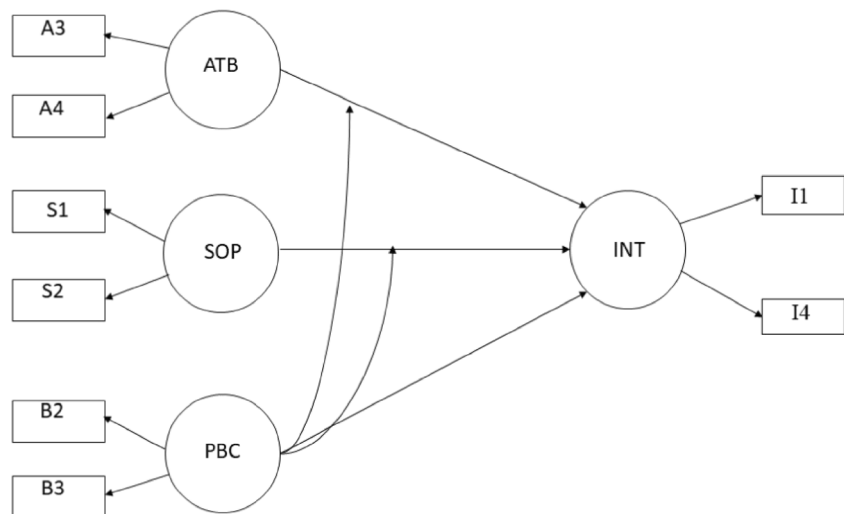
In Fig. 4: A3, A4 are indicator survey items in the TPB survey, related to attitude towards behavior (ATB), S1 & S2 for social pressure (SOP), and B2 & B3 for perceived behavioral control (PBC). ATB, SOP and PBC explain the Behavioral intentions (INT) after a week of playing the game.

I1 & I4 are indicator survey items for INT. The moderating effect of PBC on ATB and SOP (Ajzen 2019) is shown in Fig. 5. Indicator items that did not produce significant effects were removed from the model. The following were the hypotheses based on the TPB (Ajzen 2019).

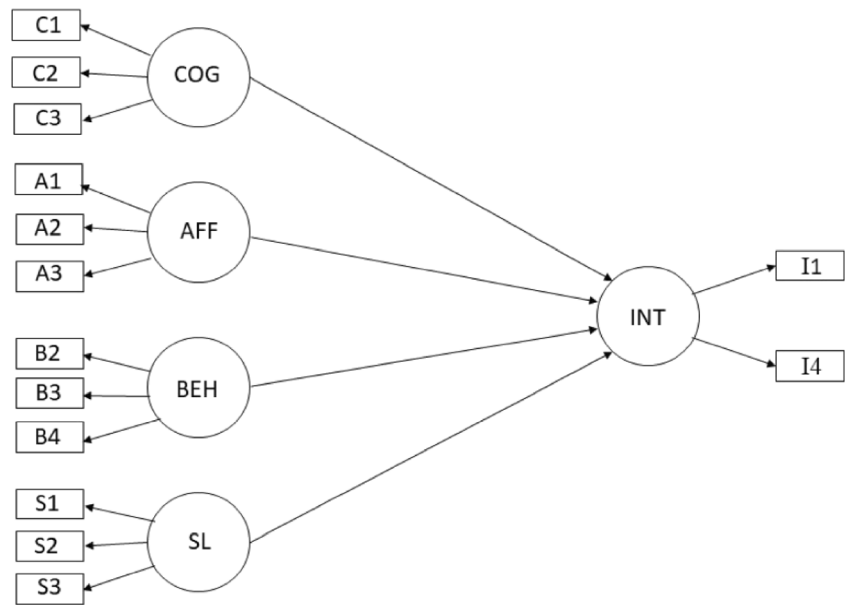
- 
- H1: Influence of ATB on INT after a week of game play is greater for Collaborative players.
  - H2: Influence of SOP on INT after a week of game play is greater for Collaborative players.
  - H3: Influence of PBC on INT after a week of game play is greater for Collaborative players.
- 

The sample size of 89 exceeded the required minimum sample size of 65 and determines that the proposed SEM

**Fig. 4** TPB model based on schematic representation of the TPB theory (Ajzen 2019)



**Fig. 5** ALI model based on the Attitudinal Learning Instrument (ALI)



model fits the data to achieve a statistical power of 80% to detect  $R^2$  values of at least 0.25 (Benitez 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 1). The lower values are not problematic because the construct validity and reliability criteria were met (Benitez et al. 2019).

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 2). 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.

**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 3 and 4). The sample size, item reliability, internal composite reliability, construct validity, and discriminant validity were established for the measurement model. The following hypotheses were tested.

- 
- |     |   |
|-----|---|
| 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. |
- 

**Step 3:** To examine attitudinal learning when played collaboratively and individually based on the ALI instrument, the model in Fig. 5 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.

Each path in the structural model in Fig. 5 denotes a hypothesis.

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- |     |   |
|-----|---|
| 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.  |
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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 5). See Table 6 for internal composite reliability, and construct validity. There were no multicollinearity issues. The above analysis indicates that the proposed model fits the data.

**Qualitative Phase** Multiple evidences were collected: (1) Observations by one researcher when participants played EnerCities, (2) Game scorecards generated at the end of the

**Table 1** 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)						
A3	Recycling waste as much as possible is worthwhile.	3.88	.77	3.88	1.11	0.67
A4	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

game, and (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 RQ3 (Plano Clark et al. 2013). The interview sample was selected based on the scores earned by the participants and their gender. Two girls, one high scorer and one low scorer, and two boys, one high scorer and one low scorer were picked from both individual and collaborative 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” (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 et al. 2020): attitude, social norms, behavioral control, prior knowledge, attitudinal learning and behaviors. Subsequently, the codes were revised based on empirical data (Miles et al. 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 and Guba 1985; Miles and Huberman 1994), and multiple researchers established investigator triangulation (Denzin 1978) and provided research rigor (Denzin 1978; Patton 2015). SmartPLS software helped establish reliability,

**Table 2** 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



**Table 3** 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)						
A3	Recycling waste as much as possible is worthwhile.	4.59	0.55	4.17	0.99	0.53
A4	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

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 (Benitez 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 based on TPB 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, SOP and PBC significantly influenced INT (Table 7) when the mediating effect of PBC on ATB and SOP were taken into consideration in accordance with the TPB Model (Fig. 4; Ajzen 2019).

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  $R^2 = 0.17$  ( $R^2$  Adjusted = 0.13) indicated moderate power, considering that this is an exploratory study (Benitez et al. 2019). The predictive relevance or  $Q^2$  values were positive for ATB, PBC and INT.

**Table 4** 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

**Table 5** ALI Measurement Model Assessment

Code	Construct/Indicator (survey items)	Individual ( <i>n</i> =45)		Collaborative ( <i>n</i> =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)						
B2	I did something new related to EVS	3.39	0.86	3.63	0.90	0.78
B3	I made changes to my behavior related to EVS	3.24	0.80	3.49	1.00	0.93
B4	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

Multi-Group Analysis was executed to examine any differences based on TPB between the game players and control group. Results: the influence of attitude towards behavior on behavioral intentions 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 8).

### Attitudinal Learning Based on 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 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

**Table 6** 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

**Table 7** 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

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 along with her partner, while CFH and her partner played the role of city developers. CML and CMH did not assume any roles as a team. 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. Discussing her team’s actions CFH said, “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.” 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.” They 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 the game facilitated cognitive learning and also affected participants emotionally, connecting them to real-life. When the resources reduced, team members took decisions collaboratively and reversed their actions to “manage power” 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,” she added. 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

**Table 8** TPB Measurement Model Results (Game players Vs Control group)

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

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. This 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, both more personal roles. 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 from the game 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.” She learned that as the population increased non-renewable energy sources decreased as shown by the monitors. She complained that it was difficult to balance nature, while making people happy was easier. 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.” 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 showing that his perceived behavioral control (PBC) had increased. 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). 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) because the

game acted as objects-to-think-with (Holbert and Wilensky 2019). In this study PBC moderated SOP and ATB producing statistically significant influences on behavioral intentions for all game players combined (Ajzen 2019). Quantitative analysis showed that PBC is a predictor of behavior 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 behavioral 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 (Janakiraman et al. 2020; Harker-Schuch et al. 2020; Wu and Huang 2015) in safe testing zones (Knol and De Vries 2011; Meya and 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 favour 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 favour 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 (Räder et al. 2014) and hence 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 1957) 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 and Bauer 2013) 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 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 and 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. 2016; Schultz 2000).

Collaborative players felt a sense of security while learning together as novices, while talking and thinking aloud, and hence had more fun (Räder 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 and 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; Räder 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. 2017).

## 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 based on the theory of planned behavior and the attitudinal learning instrument 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

## 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.

## Appendix 1

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.
16. I intend to switch off the lights when not required.
17. I learned new information about the environment.
18. I am more knowledgeable about environmental sustainability.
19. I picked up new ideas about environmental sustainability.
20. I feel excitement about the topic of environmental sustainability.
21. I feel eager to learn more about environmental sustainability.
22. I feel passionate about the environment.
23. My behaviors related to the environment have changed.
24. I did something new related to environmental sustainability.
25. I made changes to my behavior related to environmental sustainability.
26. I do things differently now with respect to environmental sustainability.
27. I talk to others about environmental sustainability.
28. I educate others about environmental sustainability.
29. I am confident discussing about environmental sustainability with others.
30. I connect with other people regarding environmental sustainability.

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