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Interdisciplinary Education Using Game Design for Electronic Waste

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ABSTRACT

This paper addresses the production of electronic waste (e-waste), which has increased drastically. We must address it immediately, as many harmful metals and hazardous gases will lead to health and environmental issues. This is due to a need for more awareness, and higher education can play a role in solving this issue. To understand e-waste, one must know electronics, chemistry, biology, and more. In addition, the topic itself needs a motivation factor to gain students' interest. Because e-waste requires knowledge of more than one field, an interdisciplinary game design education can give students the necessary knowledge for e-waste management. The paper will closely examine the different game design methodologies in the literature and how they can be applied in an interdisciplinary education to foster the topic. In addition, it addresses the need for inter-department collaboration in Universities and collaboration between Universities to give students access to knowledge and resources to understand the subject in depth. This would help students build a habit of recycling and reusing e-waste correctly, thereby preparing the next generation to build a better future.

Keywords: Electronic waste education, Game design, Interdisciplinary education, Higher education, Interdisciplinary game design, Sustainability education

INTRODUCTION

E-waste education has been addressed by many universities presently, and different fields are trying to educate students in various manners. Because e-waste is such a complex topic, the need to design education well is crucial. Some universities are concentrating on closely looking at the best methodologies that can be applied to communicate this environmental issue correctly (Chen et al., 2011). The primary focus is spreading awareness and changing students' attitudes toward the environment by providing education through institutions (Hamid et al., 2017). Emphasis is given to changing the students' behavior to achieve the proper awareness. This can be achieved by using appropriate communication mediums to educate students to spread awareness and positively change behavior towards this critical issue (Nanath and Kumar, 2021). In addition, the hazardous chemicals, the e-waste consists of gold, copper, nickel, silicon, and iron, which are some of the precious and semi-precious metals that get lost if not disposed of in the proper manner (Estrada-Ayub and Kahhat, 2014). This makes it even more critical for a thoughtful education to be planned to address this topic. Institutions must take more initiative and tie up with other institutions with existing courses,

making the knowledge more accessible. Universities can make this a one-credit or minor to motivate students to take the course and not fall back on their coursework.

As mentioned above, there is a need for immediate attention to e-waste education as there are many harmful chemicals and hazardous waste. In addition, it is essential to note that e-waste produced in 2019 was about 53.6 million metric tonnes (Mt) worldwide, and by 2030, it is predicted to reach 74 Mt, almost double in 16 years. Unfortunately, in 2019, only 17.6 percent of the e-waste produced was collected and recycled (Global E-waste Monitor, 2020). If these electronic components (electronic waste) are not disposed of correctly, they end up in open-air dumps or landfills. This electronic waste containing metals and substances produces hazardous gases and cannot be decomposed in the soil. It pollutes soil, air, and water, which causes environmental (Dwivedy et al., 2010) and health issues (Balde et al., 2017; Song and Li, 2015).

UNDERSTANDING ELECTRONIC WASTE

It is crucial to understand what e-waste is to build a good learning experience for educating students about e-waste. E-waste has many definitions: Electronic Recyclers of America (2006) defines e-waste as "All the absolute or outdated computers, televisions, cell phones, printers, PDAs, and thousands of other devices commonly used in offices, homes, and people on the go (Davis et al., 2009)." From this definition, we can see the topic itself is complex and requires the awareness of different domain knowledge, such as chemistry, electronics, biology, and many more, that must be understood. Educating students in an interdisciplinary approach can be applied to solve this issue effectively. In addition, there needs to be some motivation required for the students to learn and understand the topic with ease, and game design education can play a vital role in doing this. To summarize, an interdisciplinary game design education would help motivate and change the students' behavior to build a habit of recycling and reusing e-waste properly in their daily lives, thereby reducing the e-waste footprint in the environment.

INTERDISCIPLINARY GAME DESIGN EDUCATION

As already mentioned, the topic needs an interdisciplinary design education that can be used. It is crucial to design the education well-thought-out as the game design requires additional development costs. Motivation is the driving factor that needs to be deeply understood to create a well-developed game design.

Role of Motivation in Game Design

Based on the literature, we see that the role of motivation is the main contributor to game design. Three motivation theories can be used based on the content that is created: 1) Flow Theory of Motivation, 2) Self-determination Theory, and 3) Goal-setting Theory that helps in building the foundation

of game and game elements that facilitate learning more effectively (Grund, 2015).

Flow theory implicates a "flow-state," which profoundly engages the student in the state of flow (Nakamura and Csikszentmihalyi, 2002), thereby leading to forgetting self-reflection and awareness for achieving the rewards (Grund, 2015), distracting the players from learning as a whole. Challenges negatively impact the game design as there is an arousal of anxiety due to too many challenges. On the contrary, too few challenges lead to boredom within the game. Here, skill level is the primary driver, which is limiting as not all students can have the same skill level in the gameplay.

Self-determination Theory (SDT) is more frequently used in game design because it addresses various aspects of human nature, such as emotion, language, and motivation (Denis and Jouvelot, 2005). Deci and Ryan's Self-determination Theory (Deci, 1975) mainly addresses competence, autonomy, and relatedness, which are crucial to designing educational games. Interestingly, this theory has a motivational factor of innermost interests, leading to people acting "with a full sense of volitation and choice" (Deci and Ryan, 2000). According to Denis and Jouvelot (2005), "SDT is related to the following classification of motivation qualities: Intrinsic motivation pushes us to act freely, on our own, for the sake of it; Extrinsic motivation pulls us to act due to factors that are external to the activity itself, like reward or threat; Amotivation denotes the absence of motivation. Thus, in SDT, high degrees of motivation requires satisfaction of the innate psychological needs and are directed towards what people find interesting (intrinsic motivation) or important (well-internalized extrinsic motivation) (Deci and Ryan, 2000)."

Goal-setting Theory is, as the name implies, a goal is a motivator for individuals to perform tasks (Locke and Latham, 2002). Here, the performance is better when there are higher goals, as to achieve the goals, commitment is required (Grund, 2015). In this case, the individuals should be determined to accomplish the game elements.

To sum up, the motivators help create a better platform to design a good game based on the content requirement that needs to be communicated to the students. In the case of electronic waste education, there is a need to motivate students (both intrinsic and extrinsic) based on the student's interest in learning the topic and knowledge level of the topic itself. Here, we also need interdepartmental collaboration to understand the student level of interest and skill levels to create a motivation factor for students with different backgrounds to be engaged in the content created for effective learning equally.

Designing an Educational Game

To design an educational game along with addressing the motivating factor, having a clear understanding of the content and the goal that needs to be achieved, that is, what content the students are learning, should be considered the most critical aspect. The next aspect is regarding the age, gender, and interest level of the game designed for the students. It is vital to note that some studies show boys have better interest levels in playing a game when

compared to girls (Novak, 2015; Denis and Jouvelot, 2005). In addition, students in lower classes can be easily motivated by using badges and leaderboards compared to students with higher grades (Novak, 2015). Lastly, it also needs to be noted that not all students will have equal software knowledge of the games, as the backgrounds of students and the resources they get to access in their daily lives need to be considered.

Based on the previous literature and research on educational game design, below are some game design strategies that can be used to build a good game. One of them is making serious games to create goal-driven experiential learning to help in a deeper understanding of the topic instead of simple, entertaining games with no learning objectives (Abt, 1987). In addition, serious game design will also help improve capabilities and knowledge along with the motivation to learn the topic (Zee et al., 2012). In other words, every field needs to build games based on the area or topic with the help of the game elements (Kankanhalli et al., 2012). Alongside, game design education helps to solve real-world problems. One example is in Peekaboom, where students can enhance the computer vision algorithm by identifying objects in the given pictures (Ahn, 2006). It is vital to build an excellent educational game to achieve this understanding of the game design and game elements. It is interesting to note that serious gaming originated from the *military* and is inclined towards acquiring new skills and teaching educational content (Smith, 2010). In other words, the games are designed for educational purposes with the help of game mechanics. While students tend to play games, they tend to learn about the topic it was designed for (Charsky, 2010). For a better outcome, students are trained initially to play the game and thereby help to understand and reflect upon the content of the course (Garris, 2002). Serous gaming is a combination of learning and motivation and theories such as the Flow Theory of Motivation, Self-determination Theory, Experiential Learning Theory, Goal-setting Theory, Bloom's Taxonomy, and Constructivist learning theory cater towards helping students to learn while doing or, in this case playing the games (Abt, 1987).

When we speak of video games, it has the potential to help in designing education with features like interactivity, user-centric design, and state-of-the-art computer technology, which allows students to get the experience of learning by doing and heed deep engagement for the students. As already mentioned, game design is motivation-driven learning. When we look closer at the Self-determination Theory, we understand that it helps in social development and helps to build on competency, relatedness, and autonomy. This theory classifies it by Intrinsic motivation, external motivation, and Amotivation, as mentioned earlier. In game design, this is the key for students to invest their time and mind towards learning the content rather than just enjoying the game for entertainment. In addition, motivation helps build on long-term memory, which helps build educational games, keeping this as the core to design educational games to monitor, elaborate topics, and organize information that students can retrieve while playing the game. Games, when designed for education, need interactivity rather than static data so the students can get involved in learning. In addition, while designing educational games, the need for the right goals, such as morals, scientific, aesthetics, etc.,

needs to be clear as if the game design is too heavy on game elements such as game characters and other game elements yielding towards game aesthetics, it will lose the value of educational purpose and becomes just entertainment for students to play. When games are built in well, there are certain aspects kept in mind, one being the players get the freedom to play in a manner to get meaningful feedback, be able to practice based on the barrier of skill level, have the opportunity to build upon creativity and have an option of exploration based on their interest and lastly be able to relate and socialize in the game easily. Some studies show when educational games are played in multiplayer, the knowledge gained is more when played individually.

Storyline game design is another method where the students are motivated and engaged in meaningful learning based on the storyline. The military also adopted this for learning in the 1990s (Iuppa and Borst, 2007). The advantage of this type of game design is that it makes learning memorable and helps in applying knowledge present in complex real-world situations (Lee and Chen, 2009). In short, content like electronic waste recycling and reuse requires practice, and this kind of game design can help students to do so.

DISCUSSION

Though there are many examples of good game designs, there are areas for improvement in each case, as mentioned earlier in the paper. Some are that the game needs to keep the gender, skill level, and resource access in mind while considering any game designed for students. Another aspect is the relatedness that needs to be considered while designing a game for students. For example, in the case of storyline educational game design, if characters are added and the students fail to relate to the character, their interest level in playing the game will be low. More research needs to be done in these aspects to understand the behaviors and interest level of the students to motivate them and help them to engage in the content.

Though motivation is the key driver, having a more in-depth understanding of what drives students to achieve behavioral changes needs more research. The aspect of interdisciplinary collaborative educational game design is another aspect that is missing in the literature, and more research needs to be done as nowadays, collaboration between departments is not only a need for topics such as sustainability (specifically e-waste), on the contrary, more number of industries and companies prefer to hire students with collaboration and creative skills. This can be achieved only with interdisciplinary collaborations between the departments and having exchange programs between colleges to expose students and give them a better future.

CONCLUSION

In conclusion, game design education has a lot of opportunities, especially when we are addressing topics such as sustainability – electronic waste recycling and reuse, where motivation is an essential aspect needed to spread knowledge and awareness within the students to build a good behavioral change to learn and practice to make the environment better for present and

future generation. It is also crucial for them to know the harm it is creating to their health, and this change can help build a better society and develop better habits in their everyday lives.

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