International Journal of Serious Games

ISSN: 2384-8766
https://journal.seriousgamessociety.org/

Article

Effects of Meaningful Choices in Serious Games for Meaningful Learning

Yan Lau Wong [1], Theo Bothma[1] and Annique Smith[1]

[1]*Department of Information Science, University of Pretoria, Pretoria, South Africa*
yan.wong@up.ac.za; theo.bothma@up.ac.za; annique.smith@up.ac.za

Keywords:

Serious games
Game-based education
Meaningful learning
Meaningful choices
Game studies

Received: February 2024
Accepted: August 2024
Published: August 2024
DOI: 10.17083/ijsg.v11i3.745

Abstract

This action research study examines how meaningful choice design affects the overall meaningful learning experience of a virtual reality educational serious game. An intervention was developed to teach hazard detection in mines and was tested by mining engineering postgraduate students at a tertiary institution. Qualitative findings suggest that participants felt that the application of meaningful choice design improved the overall learning experience. This design approach empowered players to tailor their experiences based on their strengths and weaknesses, enabling them to establish a personalized flow and pace to master the content. Moreover, participants expressed that the inclusion of meaningful choice design enriched their serious game experience and, consequently, enhanced their learning outcomes.

Future research on serious games should focus on exploring replayability, quantifying the impact of positive game experiences on learning, and implementing various game design principles in educational serious games. This study advances game-based education by emphasizing the benefits of using game design techniques and positive play experiences for learning.

1. Introduction

Games in education are identified to provide multiple positive outcomes in learning [1], [2] but often fail to provide an enjoyable play experience when compared to their recreational counterparts [3], [4]. This is claimed to be a result of educational games overly focusing on content and overlooking game design [1], [3], [4]. Games for learning are unique in that a careful balance is needed between the content and gameplay [5, p. 4]. This has prompted speculations that the application of game design theories in educational games has the potential to provide other forms of educational benefits [1], [5], [6].

This article explores the application of the game design strategy of meaningful choices [7, p. 220], [8, p. 85] in an educational serious game (SG) explicitly designed to teach hazard detection. It aims to understand the effect of meaningful choices on meaningful learning. Meaningful learning is the process of acquiring knowledge by relating new information to what is already known, enhancing comprehension and the ability to apply the information effectively in various contexts[9]–[11]. Meaningful choices were explored as they focus on how games

allow players to craft personalized, meaningful experiences through intentional choices [8, p. 46], resonating with the constructivist nature of meaningful learning [10]. The study explores this relationship by identifying what a meaningful learning activity entails, identifying different design strategies for creating meaningful choices, developing a game centred around meaningful choice design strategies, and lastly, qualitatively evaluating the intervention. Participants found the application to be engaging and the overall experience to be positive. Choices allowed each learning experience to be customisable and adaptive to individual needs. Encouraging future studies to evaluate these effects quantitatively and exploring other design theories in educational SGs.

2. Literature Review

2.1 Meaningful learning

Meaningful learning is an educational theory that emphasizes the importance of relating new information to prior knowledge, thereby making the new information meaningful and easier to understand and retain [9], [11], [12, p. 2], [13]. This aligns with a constructivist view of knowledge acquisition in which knowledge is constructed by the learner [10]. It lies at the opposite end of the learning continuum from rote learning [14], with rote learning emphasizing knowledge acquisition through retention, while meaningful learning emphasises knowledge integration and transfer [12, p. 2], [14], [15].

For learning activities to be meaningful, they need to encompass five characteristics: being active, constructive, intentional, authentic, and cooperative [12, p. 3], [16], [17, p. 1]. The active characteristic describes an activity that allows for the interaction with and manipulation of the subject matter [12, p. 5], [17, p. 1]. This produces observable results and encourages students to continually construct new meanings and reflect on their understanding [12, p. 5], [17, p. 1]. The intentional characteristic refers to how learning activities should be purposeful and goal-directed [18], as clear goals allow students to focus their efforts efficiently. The authentic characteristic refers to how content must be taken out of the classroom and used practically in the real world [17, p. 2], as studies have also shown that knowledge obtained by this form of real-world application is better understood, retained, and transferred [12, p. 4], [19], [20]. Lastly, collaborative learning allows learners to share ideas and perspectives, fostering a deeper understanding by working together [12, p. 5], [17, p. 2]. These characteristics appear in no particular order as they are interlinked, and activities should strive to cover as many characteristics as possible to be designed toward the goal of meaningful learning [12, p. 5].

Meaningful learning was selected for this study as research has shown simulations, virtual reality applications, and games used in higher education have the tendency to report meaningful learning outcomes [2], [21]. This is due to their design of being reflection-based and metacognitive activities.

2.2 Meaningful choice design in games

Meaningful choices in game design refer to a game's ability to provide meaningful outcomes to a player's purposeful actions [7, p. 221], [8, p. 85], [22]. This allows players to perceive their choices as integral to the game, making actions meaningful. For example, opening moves in chess are important as they establish control of the board, develop pieces, ensure king safety, and set the stage for a favourable middlegame and endgame. This study explored the application of meaningful choices in the forms of meaningful interaction [8, p. 48], agency [23], [24], and consequences [25], [26], which was selected based on reputable literature. Each is described in more detail below.

2.2.1 Meaningful interactions

Creating great player experiences is a primary goal in game design [27]. The undeterminable nature of players means that game designers cannot directly control how players will interact with the game [8, p. 93]. Interaction between players and systems can be summarised as actions and feedback, this relationship allows players to make sense of the gameplay [7, p. 221], [28, p. 186]. Within actions, choices can be identified as conscious decisions made to overcome obstacles. Depending on the impact of these choices, they can be considered meaningful if they affect the outcome of the game [29, p. 181].

Meaning can arise from these choices in a descriptive or evaluative manner [27]. Descriptive meaning is manifested based on the relationship between player actions and the game's outcome [8, p. 48], an outcome informs players when actions are taken. This is descriptive in that it describes what had happened in the game and meaning is manifested based on the action-outcome relationship. Evaluative meaning is manifested based on how actions affect the overall structure of the game. Actions in this regard should be both discernible and integrated into the larger context of the game [27]. Discernibility refers to how perceivable feedback must be provided to indicate that a change has occurred [7, p. 277] while integrability means that not only must there be an immediate effect but the play experience should also be affected at a later stage[7, p. 221], [27].

Meaningful play is thus created by intertwining player actions into the larger context of the game. This can be achieved by providing players with discernible feedback for their actions and ensuring an integrated effect on a choice affects the rest of the game. If choices and actions have no meaning in a game, there is no reason to play the game [8, p. 225].

2.2.2 Agency

Agency in games is often referred to as the freedom and control a player has over the system [30, p. 95], [31]. Agency implies choices and choices imply various outcomes [32], thus giving a game with strong agency seemingly endless possibilities. A means to understanding agency is by looking at three forms of agency found in games: systemic, spatial, and scheduling [33].

Systemic agency arises from the system's ability to act on a meaningful decision. It is directly related to the expressiveness of the space of possibility [33], in that more meaningful decisions can be made in a richer space of possibility, for example, by providing players with a large selection of tools to tackle challenges. Spatial agency refers to the exploration element of a game. This includes exploring the physical environment and the depth of a game's system. For example, combining different tools reaps different results incentivising players to explore different combinations. Spatial agency exists as the environment, items, skills, and other objects in the game that contribute to the players' experience [8, p. 72], [33]. Scheduling agency focuses on the control over the tools granted to players to complete the challenges before them [33], for example, limiting the number of tools a player has access to can directly influence a player's choices.

Agency in games can be summarised as the relationship between player action and system response [22]. Agency exists where actions are taken freely by the players with an intent in mind, and the response from the system communicates the result of those choices [7, p. 220], [8, p. 85]. For agency to exist, players need to feel empowered by the freedom of choice, have control over the choices, and must show commitment to the results of the choices that they have made.

2.2.3 Consequences

In addition to meaningful interactions and agency, for choices in a game to be meaningful, the players need to be committed to their choices [34], [35]. Consequences can affect how players view the importance of their actions [36]. According to the decision scale, choices with little to no quantifiable impact are categorized as inconsequential, while choices that have too much

impact are labelled critical [37, p. 272]. Ideally, choices should have varying degrees of severity as continuous critical decisions can eventually lead to decision fatigue, and continuous inconsequential decisions tend to remove the sense of purpose [38]. Whether a choice is critical or inconsequential, it should still add value to the player's experience; this creates commitment [38], [39]. Critical choices alter the overall outcome of a game while inconsequential choices play the role of reinforcing behaviour, both examples commit the player toward their actions and help players develop a deep emotional connection with the game [24], [34], [35].

Choices are an integrated part of games that affect the experience greatly [16, p. 46], [32, p. 95], [36], [37], [41]-[44]. To determine the success of a decision, games need to provide enough information for players to make conscious and personal decisions [38], [39]. The effects of these choices need to be communicated; this should be in the form of feedback and how they affect the overall game. Meaningful interactions, agency, and consequences are some design strategies that can be adopted to ensure a game environment that can nurture meaningful choices.

2.3 The present study

Learning and play experiences are rarely explored in conjunction, but playing an educational SG would make the two experiences more intertwined [43], [44]. The exploration of the relationship between these experiences is limited [45], and the application of game design techniques affecting educational experiences should be more thoroughly explored [46], [47]. This study explores the relationship between the play experience, shaped by meaningful choice design, and the learning experience, provided by a virtual reality education SG. The goal is to understand the viability of using meaningful choice design in an SG to promote meaningful learning.

The following research questions guided this study:

- How do participants perceive the role of meaningful choice design in shaping the educational SG to support meaningful learning characteristics?
- What effect does the application of meaningful choice design have on the overall learning experience of the SG?

3. Methods and Materials

A virtual reality educational SG for teaching hazard detection in underground mines was developed for this study. The game was developed as a meaningful learning activity and meaningful choice design strategies were implemented in the design. The effect of the design strategies towards meaningful learning was assessed qualitatively to gain a deeper insight into the experiences of participants.

3.1 Participants

The study consisted of 11 students who had completed their studies in mining engineering at a public university in South Africa. Convenience sampling was adopted due to its practicality and efficiency in collecting data. The sample was limited to a single university and degree, the participants were studying at a postgraduate level. Participants were not a part of the teaching staff and had previous experience with an active mining site. The additional criteria were set to remove perception bias, by involving participants who did not teach the content, and to understand the applicability of the game in a real-world context.

The study acknowledges the limitations of convenience sampling due to the potential selection bias and limited generalizability. All participants matching the above description were included and invited through email. No compensation was provided to the participants as

participation was completely voluntary. Full ethical clearance was granted by the institutional ethical review board before the commencement of the study.

3.2 Material

There was no established survey targeting meaningful learning and meaningful choice at the time of the study, so an ad-hoc electronic 64-question survey was developed. The survey was separated into a pre-survey administered before the intervention and a post-survey afterwards. Pre-survey was used to gain insight into participant history with virtual reality and SG and the post-survey was conducted to gain insight towards their experience.

The survey was designed to gather insights on the prominence of each meaningful learning characteristic. The survey included a mix of 21 5-point Likert scales, 20 close-ended, and 23 open-ended qualitative questions. These questions were designed to assess the sense of meaningful learning characteristics provided by the game and the impact of the meaningful choice design.

Afterwards, a series of three focus groups with three to four participants each were conducted to gain additional insight into the meaningful choice design strategy used in the game's design. These focus groups were carried out online, providing a convenient and accessible platform for participants. Each session was recorded to ensure that all valuable information was captured accurately and later transcribed for further analysis. The focus groups consisted of nine questions following the format of opening, introductory, transitional, four-key, closing, and conclusion questions [48, p. 51]. Key questions were drafted based on the analyzed data provided by the survey.

3.3 Procedure

All participants were informed of the scope and the duration of the study – 15 minutes of pre-survey, one hour of exposure to the game, 30 minutes of post-survey and 45 minutes in focus groups. Participants were informed of their voluntary participation, and confidentiality of their information and they provided their informed consent.

Participants were assigned an individual workstation where the survey was completed and the developed game was played. After the initial stages of data analysis were completed, participants were re-invited for the focus groups.

4. Game Design

The medium of virtual reality (VR) was selected for the game because of the realistic and authentic environment that it can create [49], [50]. In addition, virtual reality is increasingly being used to simulate hazardous and high-risk working environments for training [51], [52]. These reasons support the choice of using virtual reality, as the game aimed to create an authentic learning experience in a safe space where theoretical knowledge can be applied to real-world scenarios.

The game's purpose was to teach students hazard detection skills. Hazard detection is a challenge in the mining industry because hazards in mines can go undetected even though they are considered worksite threats [53]. All mining tunnels need to be surveyed both before and after an excavation [54]; this is particularly difficult to teach practically due to the limited accessibility to these environments.

Hazard detection in the game was practised as a process of identifying geological anomalies in the walls of the tunnel based on visual cues. These visual cues include geological deformities, damage, and problematic rock formations. A qualified mining consultant was involved during the design of each fault category and helped test early and later versions of the game to ensure accuracy and realism. In the game, players report hazards found throughout the

virtual mine tunnels by marking visible faults with a tin of spray paint. The spray paint tool allowed the system to evaluate a player's understanding of a hazard based on the percentage of the total fault marked as dangerous (Figure 1).

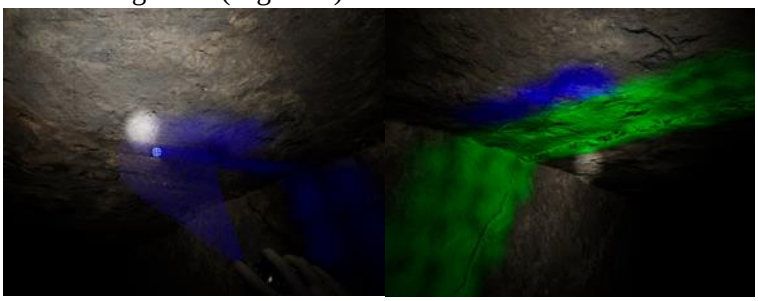

Figure 1. A player successfully identified a hazard (blue spray paint), resulting in the SG highlighting the correct selection in green

Along with the spray paint tin, players were also given a headlamp for lighting their way, and a tablet to keep track of their progress. The equipment system allowed players to customize their play experience by selecting the different quality of tools. Quality was associated with varying underlying characteristics and consequences, with some granting lasting effects (Figure 2). These characteristics affected the overall gameplay and scoring modifiers of a level. These design choices were specifically made to link choices to consequences and rewards, covered in section 2.2.3.

Figure 2. Player selecting the quality of the tablet (PDA) used in-game

Players could also select between levels of increasing size, which contain randomly generated hazards. Each level allows players to adjust the difficulty whereas higher difficulty settings generate more complex hazards. Once the player indicated that they had completed the surveying, the game would evaluate their performance. The score was generated based on success, accuracy, and time taken for level completion, with additional modifiers based on the difficulty and equipment chosen.

Although this study primarily focuses on the constructivist view of education, game elements can be framed in various learning theories. For example, scores and leader boards are often identified as game elements that support behaviourism [55]. Design choices were made to enhance the overall experience and were not limited to the context of learning theory.

4.1 Design using meaningful choices

Meaningful choices were integrated into the game as meaningful interactions, agency, and consequences. Meaningful interaction design affected the overall designs within the game, in that all players' actions needed to be both discernible and integrated into the game. A focus was placed on providing tactile, visual, and audio feedback wherever possible. For example, visual

feedback included indicators such as the level of paint left in a spray paint tin, or the highlighting of identified hazards (Figure 4).

Figure 3. (Left) Visual indicator on how much paint is left in the spray paint; (Right) Hazard being highlighted green when successfully marked

The game supported systemic, spatial, and scheduling agency in multiple ways. Systemic agency was supported by the game's random generation of hazards and the array of tools that allowed players to tackle challenges differently. Spatial agency was the exploration element of the game and how this exploration rewarded players with meaning, for example, the combination of different quality tools and the varied experience each combination provided. Unlocking of higher levels and better equipment addressed scheduling agency.

The last meaningful choice design included was consequences. Consequences existed in the game as choices that affected the score of a level and experience of the game. For example, if players selected poor equipment, the consequences were faulty equipment that hindered progression; affecting the overall experience and score. Players are likely to choose better equipment, but there were limitations on availability, stock, and credit – credits being a fixed amount provided to players per level for purchasing equipment. This resulted in more mindful decisions, making the equipment choice more meaningful for the players.

4.2 Design for a meaningful learning environment

The game was designed to create an environment that can support meaningful learning by considering the characteristics of meaningful learning. Meaningful learning activities need to encompass the following five characteristics: active, constructive, cooperative, authentic, and intentional [12, p. 3], [16], [17, p. 2]. By creating an enjoyable experience that supported the characteristics of meaningful learning, players were provided with ample opportunities for meaningful learning to manifest. It should be noted that cooperative elements were not included in this iteration of the SG.

The active characteristic was supported by the fact that players were required to actively interact with the hazards as they had to physically mark hazards in the virtual space. The constructive characteristic was supported as players needed to reflect on their understanding of hazards; this was prominent when hazard selections were marked as incorrect and players needed to re-evaluate their understanding of hazards. The authentic characteristic was addressed in that the levels were a recreation of existing mine tunnels, the tools reflected real mining tools, and the hazards reflected real-world mine hazards. The intentional characteristic was supported by the how game provided a list of varying and randomly generated hazards to be identified per level, making the experience goal-directed towards teaching hazard detection.

5. Results

The analysis of the survey (S) and focus group (F) data identified several key themes that encapsulate participants' perspectives on the game's meaningful learning nature, their views on

the meaningful choice strategies applied, and the effect of design choices on the learning experience.

The constant comparative method, as outlined by Glaser and Strauss [56], was employed for data analysis. The analysis began concurrently with data collection, as this allowed newly discovered data to affect further data-gathering methods, similar to Iterative Thematic Inquiry [57]. Open coding was initially conducted, identifying concepts and patterns in the data. Codes were compared within and across the data to refine and develop categories. Axial and selective coding was further conducted to derive meaning from the data. The resulting emerging categories were continually compared and contrasted to identify commonalities and variations.

5.1 Survey Findings

The survey was constructed to qualitatively inquire whether the characteristics of meaningful learning were prominent whilst playing the game. The survey further inquired about which features contributed towards these characteristics in an open-ended manner. **Errore. L'origine riferimento non è stata trovata.** contains a list of features identified from participants' responses that satisfied the different characteristics of meaningful learning. Each is discussed in more detail below.

Table 1. Participant identified features and their contribution towards the characteristics of meaningful learning

Game Models	Active	Intentional	Authentic	Constructive
Realistic representation	X	X	X	X
Hazard identification system	X	X	X	X
Equipment system	X	X	X	
Random generation of hazards	X	X	X	

5.1.1 Realistic Representation

Many participants identified realistic representation as a core feature that contributed to all meaningful learning characteristics. Participants remarked on the benefit of realistic representation in the game, emphasizing the educational benefits of having a realistic applicational environment. This made the game feel goal-directed (intentional) and engaging (active) and was also noted to build on what was taught in class to develop a deeper understanding of the topic.

> *S-P1: "The sound effects and the lighting are unbelievably realistic and create a great experience that accurately portrays what you would typically see underground in a real mining environment. It is something that would benefit any person involved with underground mining."*

> *S-P2: "Even though we learn about hazards, our ability to identify them in a mining environment cannot be tested or applied by us. This [the game] allows for the application of knowledge in a mining environment. Being able to see them in real real-life mining environment made the connection between theory and practicality that normally lacking, this helps bridge this issue."*

These participant responses support why realistic representation satisfies all characteristics of meaningful learning. The first quote expresses how a realistic representation was achieved and that realism could provide educational benefits for students involved with underground mining, supporting the authentic characteristic. The second quote emphasizes how the environment provides a space to apply classroom-taught knowledge, supporting the intentional, active, and constructive characteristics of meaningful learning. Together providing support for realistic representation to be a contributing feature towards the characteristics of meaningful learning.

5.1.2 Hazard Identification System

Participants felt that the designed hazard identification system made the learning process actively engaging. Employing a tin of spray paint to mark hazards was challenging but realistic, requiring a methodical and intentional identification process. Immediate feedback allowed players to reflect on their selections, which further improved their understanding of the hazards.

> *S-P3: "I felt in control, that the entire responsibility lies on me to identify the hazards, and the game's ability to tell you when you've identified something correctly is very constructive."*

> *S-P4: "Being able to correctly identify all the hazards despite the difficulty of the level made it felt goal-directed. I have always been unclear with the identification of potholes [hazard type] underground, but today, I mastered the skill."*

Both quotes highlight how the system can provide meaningful feedback allowing students to reflect on the learning process and providing a constructive learning environment. The mechanic of hazard identification replicates the real-world process making the interaction intentional, active, and authentic.

5.1.3 Equipment system

Being able to customise the conditions for identifying hazards made the activity engaging. Participants showed intentional decision-making based on the goals and needs of the task. The limitations placed on tool availability were also well-received, with participants claiming that this feature reflected real mines' budget limitations for safety and production.

> *S-P1: "For me, it was the option of improving the conditions that come at a cost and also has a limit to it… made me more active because I had to figure out which factors were more important…"*

> *S-P2: "This is the reality of mines in a sense that they also have a budget limit and have to maximize safety and production based on it."*

> *S-P6: "The tablet is what made the experience feel intentional, it enabled a more systematic way of approaching the game and did a great job in giving clear instructions."*

The three quotes above were selected to express the equipment system's intentional nature, a need for active participation, and relatedness to the real-world operation of mines. The constructive characteristic was not identified but made sense as it is associated with gaining a deeper understanding and retention of information. The consequence-based equipment system did not build on enhancing the hazard detection process but rather the gameplay experience based on each participant's individual goals. This is noteworthy as design elements

contributing to the play experience, instead of learning, can still be a contributing element to how intentional, active, or authentic an activity can feel.

5.1.4 Random generation

The random generation of hazards added a level of replayability and represented how hazards appeared in mines. This made the identification process dynamic, further testing players' understanding of hazards. Hazards are complex and the random generation within the developed game was limited. This suggests that a more complex random generation system could reap better educational results and experience.

> *S-P5: "The random hazard putting features is good, allows you to engage again with an active mindset of doing something. There was a way we can do it again and again."*

> *S-P7: "The complexity of the layout from one level to another helped in my understanding, in that how big or long the tunnels were enabled me to quickly response in finding the features. Being able to adjust this made it feel productive."*

The above responses from participants showcase how random generations supported the constructive characteristic by allowing players to repeat and reflect on the identification process while still being intentional and active, as players need to seek out hazards while practising the skill.

5.2 Focus Group Themes

Focus groups were conducted after the survey and focused on understanding the effects of the meaningful choice design strategy implemented in the game. Without specific mentions of the application of meaningful interactions, agency, or consequences, participants were asked to provide feedback based on what they found to be memorable within the game and their views on the implementation of the system (identification, equipment, and level customization). Within the coded data, two emergent themes were identified that provided invaluable insights into the application of meaningful choices.

5.2.1 Theme 1 - Choices personalized the learning experience

Data indicated that participants found the equipment system an interesting and fun mechanic that allowed them to shape their learning experience while playing the game as indicated by the following quote from F-P1.

> *F-P1: "It makes learning exciting; it will change the game every time, and you can do something different. It's like any game. You can play it thousands of times, but if you can do something slightly different each time, it almost opens up a new tree of decision-making."*

Participant F-P5 expressed how the system's depth can be seen in the game's scheduling agency, providing replayability and allowing participants to make informed choices tailored to their strengths and weaknesses.

> *F-P5: "The tools are fit-for-purpose, for our own strengths and weaknesses, to a point where if you are good with directions underground or good at direction finding, we just need to get you some lighting."*

Participant F-P4 indicated how the consequences of the equipment choices can be related to some real-world experiences adding authentic and educational values. It provided a means to reflect, specifically in cases where the weight of a decision can be immediately felt.

F-P4: "The best part with this is the fact that you can make decisions and learn from them without the direct real consequences… You know, at the end of the day, you get a certain result, and that result can help you reflect, and it can help you learn based on the decisions that you made."

The ability to customize the gameplay was viewed to enrich the overall learning experience. Customisation allowed players to alter their learning experiences based on self-identified strengths and weaknesses. It is also identified as a means to give SG a property of replayability, allowing players to replay the game for mastery. This suggests that similar design strategies should be adopted by other forms of educational games.

5.2.2 Theme 2 - Consequences are educational but should increase at a gradual pace

Data indicated that the use of consequences was effective in communicating the idea of choice and agency. Participants voiced this as regret, trade-offs, or referring to their choices as poor. This is shown in the following quote from participant F-P7.

F-P7: "I think it was one time I just picked wrong and kept getting lost. It made me annoyed and anxious, but eventually I got it. Very interesting to see, like, when you make poor choices, you just regret it for a long time."

Participants felt having more severe consequences would impede the learning process as they would induce negative emotions of fear and stress. This is better summarised by the following quote by F-P6.

F-P6: "I want to say it would impede the learning process and doesn't inspire learning if the consequences are too impractical. You'd be excessively cautious with your decisions, so it takes you way longer to come to conclusions. You cannot play a game, if it means it's always a life or death situation."

Contradictorily, some participants also indicated a need for severe consequences. F-P1 was one such participant and suggested that if severity was to be scaled gradually the resulting system would be educational, especially when linked to real-world consequences taught within the theory.

F-P1: "It's good to play these things on your own and learn in your own space, but you certainly need consequences. I think it would really be educational for most of us, because we only know about lists and the consequences on paper."

F-P7 builds on this idea by suggesting the idea that gradually introducing more severe consequences would allow players to adapt to the game and understand the role of the consequences in their learning experience.

F-P7: "If it's for exposure so you will be mindful of the consequences and not make reckless decisions. Then, yeah, it makes sense to heighten or amplify the consequences. I think the best thing would be maybe give them time to adjust to the game, and how it is, and then bring that later in, because once

they understand how the scenario works, we can bring in the real effects and implications of those decisions."

These findings suggest that appropriate consequences can further enhance the educational value of SGs. It could help learners better understand the outcomes of their actions and lead to better decision-making and accountability.

6. Discussion

The findings suggest that playing this educational SG can be considered a meaningful learning activity. Characteristics can stem from either the medium chosen for said game or how the core mechanic of the game was constructed. Meaningful choice design strategies implemented were also identified as contributing features towards the meaningful learning nature of the game, suggesting that the application of these strategies would encourage meaningful learning within the SG. The core activity of identifying hazards and customizable equipment systems was built based on the understanding of meaningful interactions, agency and consequences.

Participants found the game to be constructive, providing a better context for the content taught in class and helping improve their overall understanding of the topic. This supports the use of SGs and game-based interventions as teaching aids resonating with existing literature [58]–[60].

Several properties were also identified to have a noticeable impact on the constructivist learning nature of the SG, most notably being the game's ability to provide constant feedback whilst playing. Constant feedback allowed participants to reflect on their decisions in real time and keep track of their learning progress. This is invaluable as reflection allows participants to determine their strengths and weaknesses, allowing them to adjust settings in future sessions to cater to their own learning needs [61]–[63]. This would not have been possible without the inclusion of meaningful interactions and consequences.

The various forms of agency enabled customization of the learning experience. These customization features allowed players to shape their learning experiences accordingly, based on the previously mentioned strengths and weaknesses. Thus, they created a unique flow and pace to achieve mastery over the content, further strengthening the learning process.

Although the study cannot conclusively claim that meaningful choice design techniques would enhance the overall learning experience, findings do suggest that participants viewed the application of meaningful choice design as one that provides many educational benefits. It must also be noted that meaningful choice design was not identified as the sole contributor in demonstrating the characteristics of meaning learning within the SG, suggesting that these techniques should be applied in various forms for them to work harmoniously with the underlying game system to support meaningful learning.

These findings contribute to existing research as they highlight the potential of game design techniques when used in game-based learning applications such as SG. The study's findings resonate with other studies in that games can foster meaningful learning [64]–[66] and that meaningful choices can create a personalized experience [8, p. 46] further allowing players to learn at their own pace and flow [67], [68].

6.1 Future Research

This study did not measure the learning effect of SGs quantitatively, but rather qualitatively collected data based on participants' experience to provide insight to steer future studies. It would therefore be helpful for a study to be conducted for the collection of quantitative data with a larger number of respondents to statistically measure the impact of the game on students' performance.

The study identified replayability as a crucial component for SGs and should be explored further. Replayable games are not just designed as a single experience, but rather in a manner that replaying is a crucial part of advancing and mastering the game. It can also become an adaptive feature for the players, as newer, more authentic, and more complex scenarios can be generated with each subsequent playthrough, which not only allows players to obtain mastery but also creates a more complex mental model of the material based on how the replayability was implemented. Future research should investigate strategies for applying replayability to SGs. This would involve developing an understanding of how to create meaningful replayability and strategies for adapting the learning content of scaling difficulties to such SGs.

6.2 Limitations

Our study only included participants from a specific demographic, that of being from the same university and educational background, and the richness of the data may differ due to demographic diversity. As the study is conducted based on participant knowledge, this would affect the goal of meaningful learning. The intervention period was relatively short, and its impact may be subject to change over an extended timeframe. As such, future research should aim to recruit participants from various backgrounds to ensure a broader representation of perspectives and an extended intervention duration could provide additional insights into the sustained effects of the educational SG.

While the ad-hoc survey provided valuable insights, there are several limitations to consider. The survey's design and implementation were done quickly, which may have impacted the comprehensiveness and reliability of the questions. The lack of pre-testing and standardization may affect the consistency and validity of the findings. Future research should address these limitations by using more rigorous survey methodologies.

While our study offers valuable insights, it is crucial to acknowledge the limitations associated with our convenient sampling method. It lacks the randomization necessary to ensure that every member of the population has an equal chance of being selected. While our study provides valuable preliminary insights, future research endeavours should prioritize the use of more rigorous sampling methods to mitigate these limitations and enhance the generalizability of our results.

7. Conclusions

Educational SG when combined with meaningful choice design is perceived by players to be a promising tool for personalized learning and supports the characteristics of meaningful learning. Meaningful choice was applied in the form of meaningful interactions, agency and consequences, this resulted in an engaging and positive learning experience. Participants identified realistic representation, hazard identification system, equipment system, and random generation of hazards as features that demonstrate meaningful learning characteristics. Having customizable options in these forms allowed students to tailor their learning based on their strengths and weaknesses. These findings help answer the research question of how participants perceive meaningful choice design in shaping the educational serious game to support meaningful learning characteristics and the effect meaningful choice design has on the overall learning experience.

This suggests that the application of other game design techniques holds significant potential in educational applications which could enhance the effectiveness and accessibility of education in diverse contexts, and that various techniques should be further explored and integrated into different forms of learning applications and curricula. Further research into these topics could open doors to personalized learning experiences that transcend traditional boundaries and push for more cohesive learning applications.

References

[1] M. Qian and K. R. Clark, 'Game-based Learning and 21st century skills: A review of recent research', *Computers in Human Behavior*, vol. 63, pp. 50–58, Oct. 2016 [Online]. Available: 10.1016/j.chb.2016.05.023.

[2] D. Vlachopoulos and A. Makri, 'The effect of games and simulations on higher education: a systematic literature review', *Int J Educ Technol High Educ*, vol. 14, no. 1, p. 22, Dec. 2017 [Online]. Available: 10/gft5bp.

[3] M. Passarelli et al., 'Educational games as a motivational tool: Considerations on their potential and limitations', 2019[Online]. Availablehttps://shura.shu.ac.uk/24834/[Accessed: 21November2023].

[4] K. Squire and H. Jenkins, 'Harnessing the power of games in education', *Insight*, vol. 3, no. 1, pp. 5–33, 2003.

[5] J. L. Plass et al., *Handbook of Game-Based Learning*. MIT Press, 2020.

[6] N. N. Blackburn and R. E. Cardona-Rivera, 'OGrES Welcome! Toward a Systematic Theory for Serious Game Design', in *Extended Abstracts of the 2021 Annual Symposium on Computer-Human Interaction in Play*, 2021, pp. 242–248 [Online]. Available: 10.1145/3450337.3483460.

[7] J. Schell, *The art of game design a book of lenses*. Boston: Elsevier/Morgan Kaufmann, 2008[Online]. Availablehttp://www.sciencedirect.com/science/book/9780123694966[Accessed: 10August2014].

[8] K. Salen and E. Zimmerman, *Rules of play: game design fundamentals*. Cambridge: MIT Press, 2003.

[9] D. P. Ausubel, *The psychology of meaningful verbal learning*. Oxford, England: Grune & Stratton, 1963.

[10] J. G. Vargas-Hernández and O. C. Vargas-González, 'Strategies for meaningful learning in higher education', *Journal of Research in Instructional*, vol. 2, no. 1, pp. 47–64, 2022 [Online]. Available: 10.30862/jri.v2i1.41.

[11] E. A. Ashburn and R. E. Floden, *Meaningful Learning Using Technology: What Educators Need to Know and Do*. Teachers College Press, 2006.

[12] J. L. Howland et al., *Meaningful Learning with Technology*. Pearson Education Limited, 2013.

[13] Y.-M. Huang and P.-S. Chiu, 'The effectiveness of a meaningful learning-based evaluation model for context-aware mobile learning: Context-aware mobile learning evaluation model', *British Journal of Educational Technology*, vol. 46, no. 2, pp. 437–447, Mar. 2015 [Online]. Available: 10.1111/bjet.12147.

[14] D. P. Ausubel, 'A subsumption theory of meaningful verbal learning and retention', *Journal of General Psychology; Provincetown, Mass., etc.*, vol. 66, pp. 213–224, Apr. 1962 [Online]. Available: 10.1080/00221309.1962.9711837.

[15] R. E. Mayer, 'Rote Versus Meaningful Learning', *Theory Into Practice*, vol. 41, no. 4, pp. 226–232, Nov. 2002 [Online]. Available: 10.1207/s15430421tip4104_4.

[16] D. H. Jonassen and D. H. Jonassen, *Learning to solve problems with technology: a constructivist perspective*. Upper Saddle River, N.J.: Merrill, 2003.

[17] D. Hung and M. S. Khine, Eds., *Engaged learning with emerging technologies*. Dordrecht: Springer, 2006.

[18] R. C. Schank, 'Goal-Based Scenarios: A Radical Look at Education', *Journal of the Learning Sciences*, vol. 3, no. 4, pp. 429–453, Oct. 1994 [Online]. Available: 10.1207/s15327809jls0304_5.

[19] M. M. Lombardi and D. G. Oblinger, 'Authentic learning for the 21st century: An overview', *Educause learning initiative*, vol. 1, no. 2007, pp. 1–12, 2007.

[20] K. Roach et al., 'How authentic does authentic learning have to be?', *Higher Education Pedagogies*, vol. 3, no. 1, pp. 495–509, 2018 [Online]. Available: 10/gjg4v6.

[21] G. Lampropoulos and Kinshuk, 'Virtual reality and gamification in education: a systematic review', *Education Tech Research Dev*, Mar. 2024[Online]. Availablehttps://link.springer.com/10.1007/s11423-024-10351-3[Accessed: 11June2024].

[22] K. Tanenbaum and T. J. Tanenbaum, 'Commitment to Meaning: A Reframing of Agency in Games', in *Digital Arts and Culture*, 2009[Online]. Availablehttps://escholarship.org/uc/item/6f49r74n[Accessed: 7September2023].

[23] B. Bódi, *Videogames and Agency*. Taylor & Francis, 2022.
[24] D. Muriel and G. Crawford, 'Video Games and Agency in Contemporary Society', *Games and Culture*, vol. 15, no. 2, pp. 138–157, Mar. 2020 [Online]. Available: 10.1177/1555412017750448.
[25] W. Toh and D. Kirschner, 'Self-directed learning in video games, affordances and pedagogical implications for teaching and learning', *Computers & Education*, vol. 154, p. 103912, 2020 [Online]. Available: 10/gg2v3s.
[26] G. H. Iten et al., 'To Save or To Sacrifice?: Understanding Meaningful Choices in Games', in *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*, Amsterdam The Netherlands, 2017, pp. 495–502[Online]. Availablehttps://dl.acm.org/doi/10.1145/3130859.3131309[Accessed: 13April2022].
[27] Zimmerman Eric and K. Salen, 'Game design and meaningful play', *Handbook of computer game studies*, vol. 59, p. 79, 2005.
[28] R. Koster, *Theory of Fun for Game Design*. O'Reilly Media, Inc., 2013.
[29] E. Al, *Well Played 3.0: Video Games, Value and Meaning*. Lulu.com, 2011.
[30] J. H. Murray, *Hamlet on the Holodeck: The Future of Narrative in Cyberspace*. MIT Press, 2017.
[31] R. Sawyer et al., 'Is More Agency Better? The Impact of Student Agency on Game-Based Learning', in *Artificial Intelligence in Education*, vol. 10331, E. André, R. Baker, X. Hu, Ma. M. T. Rodrigo, and B. du Boulay, Eds. Cham: Springer International Publishing, 2017, pp. 335–346[Online]. Availablehttp://link.springer.com/10.1007/978-3-319-61425-0_28[Accessed: 20September2022].
[32] J. Juul, 'The Game, the Player, the World: Looking for a Heart of Gameness', *Plurais - Revista Multidisciplinar*, vol. 1, no. 2, 2010[Online]. Availablehttps://www.revistas.uneb.br/index.php/plurais/article/view/880[Accessed: 6September2023].
[33] M. Worch, 'Player stories and designer stories', in *Game Developers Conference*, 2012.
[34] B. Morrison, (2013, November.19), *Meaningful Choice in Games: Practical Guide & Case Studies*. [Online]. Available: https://www.gamedeveloper.com/design/meaningful-choice-in-games-practical-guide-case-studies. [Accessed: 16 Mar. 2020].
[35] S. Zeidan Mellqvist and E. Kappler, 'Meaningful Choices: A closer look at the choice design of Detroit: Become Human'. 2022.
[36] J. L. Nay and J. P. Zagal, 'Meaning without consequence: virtue ethics and inconsequential choices in games', in *Proceedings of the 12th International Conference on the Foundations of Digital Games*, Hyannis Massachusetts, 2017, pp. 1–8[Online]. Availablehttps://dl.acm.org/doi/10.1145/3102071.3102073[Accessed: 22September2022].
[37] T. Fullerton et al., *Game Design Workshop: Designing, Prototyping, & Playtesting Games*. CRC Press, 2004.
[38] T. Fullerton et al., (2004, March.10), *Gamasutra - Improving Player Choices*. [Online]. Available: https://www.gamedeveloper.com/design/improving-player-choices. [Accessed: 10 Mar. 2020].
[39] S. Meier, 'Interesting decisions', in *Game Developers Conference*, 2012, vol. 12.
[40] M. M. Cruz-Cunha, Ed., *Handbook of Research on Serious Games as Educational, Business and Research Tools:* IGI Global, 2012[Online]. Availablehttp://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-4666-0149-9[Accessed: 16January2019].
[41] S. Domsch, *Storyplaying: agency and narrative in video games*. Boston: De Gruyter, 2013.
[42] R. Cardona-Rivera et al., 'Foreseeing Meaningful Choices', *Proceedings of the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment*, vol. 10, no. 1, pp. 9–15, 2014 [Online]. Available: 10/gspgsn.
[43] M. Bertolo and I. Mariani, 'Game and play as means for learning experiences', in *INTED2013 Proceedings*, 2013, pp. 698–707[Online]. Availablehttps://library.iated.org/view/BERTOLO2013GAM[Accessed: 24January2024].
[44] F. 'Floyd' Mueller et al., '"Erfahrung & Erlebnis": Understanding the Bodily Play Experience through German Lexicon', in *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction*, Sydney NSW Australia, 2020, pp. 337–347[Online]. Availablehttps://dl.acm.org/doi/10.1145/3374920.3374926[Accessed: 24January2024].
[45] H. Almås et al., 'Reimagining how to understand learning game experiences: a qualitative and exploratory case study', *Smart Learn. Environ.*, vol. 10, no. 1, p. 14, Feb. 2023 [Online]. Available: 10/gthdf8.

[46] N. Pellas et al., ‘A Systematic Literature Review on the User Experience Design for Game-Based Interventions via 3D Virtual Worlds in K-12 Education’, *Multimodal Technologies and Interaction*, vol. 5, no. 6, p. 28, Jun. 2021 [Online]. Available: 10/gnjm7v.
[47] D. Zhao et al., ‘Game-Based Learning: Enhancing Student Experience, Knowledge Gain, and Usability in Higher Education Programming Courses’, *IEEE Transactions on Education*, 2022 [Online]. Available: 10.1109/TE.2021.3136914.
[48] M. M. Hennink, *Focus group discussions*. Oxford: Oxford University Press, 2014.
[49] F. Yang and Y. M. Goh, ‘VR and MR technology for safety management education: An authentic learning approach’, *Safety science*, vol. 148, p. 105645, 2022 [Online]. Available: 10/gp72hn.
[50] V. L. Lowell and D. Tagare, ‘Authentic learning and fidelity in virtual reality learning experiences for self-efficacy and transfer’, *Computers & Education: X Reality*, vol. 2, p. 100017, 2023 [Online]. Available: 10/gtftds.
[51] J. Tichon, ‘Training Cognitive Skills in Virtual Reality: Measuring Performance’, *CyberPsychology & Behavior*, vol. 10, no. 2, pp. 286–289, Apr. 2007 [Online]. Available: 10/fbrd9k.
[52] X. Li et al., ‘A critical review of virtual and augmented reality (VR/AR) applications in construction safety’, *Automation in Construction*, vol. 86, pp. 150–162, 2018 [Online]. Available: 10/gcx7ss.
[53] B. M. Eiter et al., ‘Defining hazard from the mine worker’s perspective’, *Mining engineering*, vol. 68, no. 11, p. 50, Nov. 2016 [Online]. Available: 10.19150/me.6832.
[54] D. R. Hanson et al., ‘Advanced techniques in site characterization and mining hazard detection for the underground coal industry’, *International Journal of Coal Geology*, vol. 50, no. 1, pp. 275–301, May 2002 [Online]. Available: 10.1016/S0166-5162(02)00121-0.
[55] A. Aziz Hussin et al., ‘Using instructional games in an open and distance learning environment’, *International Journal of Modern Languages and Applied Linguistics (IJMAL)*, vol. 5, no. 2, pp. 70–85, 2021 [Online]. Available: 10/gtxk2v.
[56] B. G. Glaser and A. L. Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Transaction Publishers, 2009.
[57] D. L. Morgan and A. Nica, ‘Iterative Thematic Inquiry: A New Method for Analyzing Qualitative Data’, *International Journal of Qualitative Methods*, vol. 19, p. 1609406920955118, Jan. 2020 [Online]. Available: 10/gk5zjw.
[58] R. Tahir and A. I. Wang, ‘Codifying Game-Based Learning: Development and Application of LEAGUE Framework for Learning games’, *69-87*, 2020[Online]. Availablehttps://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2677641[Accessed: 13February2024].
[59] I. Voulgari et al., ‘Digital Games as Learning Tools: Mapping the Perspectives and Experience of Student Teachers in Greek Universities’, in *Research on E-Learning and ICT in Education*, T. Bratitsis, Ed. Cham: Springer International Publishing, 2023, pp. 21–38[Online]. Availablehttps://link.springer.com/10.1007/978-3-031-34291-2_2[Accessed: 12February2024].
[60] W. Feungchan, ‘Serious Games and Applications for Special Education in the VUCA World’, in *Interdisciplinary Perspectives on Special and Inclusive Education in a Volatile, Uncertain, Complex & Ambiguous (Vuca) World*, Emerald Publishing Limited, 2023, pp. 203–218[Online]. Availablehttps://www.emerald.com/insight/content/doi/10.1108/S1479-363620230000020013/full/html[Accessed: 13February2024].
[61] F. H. Akbar and P. A. Tyas, ‘Studentsâ€™ Predominant Learning Style in EFL Writing Class’, *EDUCAFL: Journal on Education of English as Foreign Language*, vol. 5, no. 1, pp. 28–34, Jan. 2022 [Online]. Available: 10/gthgw6.
[62] T.-C. Hsiao et al., ‘Students’ Performances in Computer Programming of Higher Education for Sustainable Development: The Effects of a Peer-Evaluation System’, *Frontiers in Psychology*, vol. 13, p. 911417, 2022 [Online]. Available: 10/gthgw4.
[63] H. Utunen et al., ‘Facilitating Training Simulations for Health Emergency’, in *Gaming, Simulation and Innovations: Challenges and Opportunities*, Cham, 2022, pp. 42–52 [Online]. Available: 10/gthgw5.
[64] M. Johansson et al., ‘How to design for meaningful learning – finding the balance between learning and game Components’, presented at the Proceedings of the European Conference on Games-based Learning, 2014, vol. 1.
[65] K. Flanagan, ‘Creating Meaningful Learning Environments Through Games: The Case for Measuring Play’, PhD Thesis, University of Georgia, 2020[Online].

Availablehttps://search.proquest.com/openview/23d1496654a586e66e28361d75cb12bb/1?pq-origsite=gscholar&cbl=18750&diss=y&casa_token=PTkbYEAxEycAAAAA:DoB_uf39J3DmROrajUf8GiqnYD4WKszh5D-fHq7QBQpzeEVOWoSHCbvcnBWQn4sDUN7kaTcL6Ro[Accessed: 27January2024].
[66] D. B. Clark et al., 'Academically meaningful play: Designing digital games for the classroom to support meaningful gameplay, meaningful learning, and meaningful access', *Computers & Education*, vol. 194, p. 104704, Mar. 2023 [Online]. Available: 10/gtf3rt.
[67] A. Shemshack and J. M. Spector, 'A systematic literature review of personalized learning terms', *Smart Learn. Environ.*, vol. 7, no. 1, p. 33, Dec. 2020 [Online]. Available: 10/gpwsq9.
[68] Y. Ha and H. Im, 'The Role of an Interactive Visual Learning Tool and its Personalizability in Online Learning: Flow Experience.', *Online Learning*, vol. 24, no. 1, pp. 205–226, 2020 [Online]. Available: 10/gtf3rv.