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Chapter · February 2025

DOI: 10.1007/978-3-031-80475-5_24

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Lessons upon Dislikes: Educational Game Design Principles from Players' Negative Feedback

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Abstract. This study examines digital game-based learning (DGBL), emphasizing its potential to engage learners with sustained motivation for educational advancement. Despite existing guidelines, there's a lack of large-scale studies using player feedback for game design improvement. Our research, involving over 900 players and the game Mission HydroSci, employs mixed methods to (1) identify gameplay challenges, and (2) extract design principles from negative feedback. The results reveal key factors hindering engagement and suggest design changes for better educational outcomes in DGBL. This work contributes actionable guidelines for evidence-based educational game design, underscoring the importance of holistic design and player feedback in the iterative development process.

Keywords: Digital Game-based Learning, Serious Games, Dislikes, Challenges, Design Principles, User Experience, Human-Computer Interaction

1 Introduction

Effectively educating students with diverse learning preferences remains a global challenge, particularly in conveying complex concepts and theories that require sustained motivation and engagement. Even sophisticated educational technologies such as artificial intelligence-powered adaptive learning tools may lose their effectiveness if they cannot engage learners over time. Researchers have emphasized that motivated engagement is crucial for significant educational advancements [1]. In this milieu, video games are increasingly recognized in educational research for their ability to captivate and motivate learners. They offer simulated environments that emulate real-world situations, providing interactive experiences, game mechanics, and thoughtfully designed tasks that promote ongoing engagement, learning, and mastery. Academics suggest that video games may facilitate

acquiring new knowledge and edge and skills [2]. Empirical studies indicate that digital games can bolster learning through cognitive processes, including inductive reasoning [3], decision-making [4], and motivation [5]. Growing evidence shows that digital games can lead to significant learning outcomes across various disciplines, such as mathematics [6], science [7], and language learning [8], bolstering the case for integrating game-based learning (GBL) into educational frameworks [9].

Despite these advancements, the literature reveals a nuanced gap in our understanding of how specific game design choices impact student engagement. While the efficacy of GBL in enhancing motivation and cognitive skills is well-documented, research seldom delves into the granularity of design principles and their direct correlation with engagement levels [10, 11]. This oversight hampers the translation of empirical findings into practical guidelines for educational game developers aiming to optimize pedagogical effectiveness. Addressing this gap, our study aims to elucidate the intricate dynamics between game design and student engagement. By focusing on students' experiences with Mission HydroSci (MHS) [12, 13], we pioneer a detailed investigation into the effects of design choices on engagement. Our analysis narrows down to a critical examination of one facet of player feedback: the challenges encountered and the less appealing aspects of the game. This scrutiny is poised to contribute to a set of design principles that benefit both MHS and future educational games, thereby extending existing practices of iterative development in educational game design as advocated by scholars such as Laine and Lindberg [1] and Coleman and Money [14].

In doing so, we underscore the importance of seeking end-user feedback following gameplay as a crucial measurement step for GBL studies. Such feedback is pivotal in refining design principles and enhancing the deployment of these principles, ultimately improving future educational games [15, 16]. Iterative development, recommended by educational game design luminaries [16–19], promises to yield evidence-based evaluations of the interplay between game design and pedagogical content, assess long-term learning effects, and aid in refining reflective teaching and learning practices.

Thus, our research is strategically positioned at the intersection of game design and pedagogy, aiming to provide evidence-based insights, extracted from large-scale end-users' viewpoints, into how design choices can be optimized to enhance student engagement. We investigate the following research questions (RQs):

- RQ1: What difficulties or challenges did students face during the gameplay?
- RQ2: What design principles can we draw for effective educational game development from students' negative perceptions of the gameplay?

Our inquiry not only addresses a critical gap in the literature but also offers a nuanced understanding of the relationship between game design and its pedagogical impact, setting the stage for the development of more engaging and educationally effective games.

2 Literature Review

2.1 The Development of Game-based Learning

The history of game-based learning can be traced back thousands of years when people applied Kalaha, Xiangqi, and Chess in various educational settings [20]. Digital Game-Based Learning (DGBL), defined by Prensky [21] as applying the fun features of digital games in educational settings, however, emerged in the late 20th century as educators and technologists recognized the potential of games to captivate and motivate learners [21], but has evolved significantly since its inception, intertwining the engaging aspects of digital games with educational content to enhance learning/training experiences, learning/training outcomes, and learners/trainees' attitudes toward the learning content [22].

In recent years, advancements in technology have dramatically transformed DGBL. Virtual and augmented reality have made DGBL more compelling learning experiences [23]. Artificial intelligence and adaptive learning algorithms have enabled the creation of highly personalized and engaging learning experiences [24]. These technologies allow for engaging experience and optimized cognitive loads [25], instant feedback [26], adaptive difficulty levels [27], and immersive environments [28] that cater to a wide range of learners with various characteristics. The advent of smartphones and tablets further propelled DGBL, making educational games more accessible and interactive [29]. Today, DGBL is utilized in various contexts, from primary education to corporate training, demonstrating its versatility and effectiveness as a complementary tool to traditional learning methods [30]. The ongoing research and development in this field continues to push the boundaries of how games can be used for educational purposes, promising even more innovative and impactful learning experiences in the future.

DGBL has found applications across a diverse array of domains and disciplines. In the realm of education, it has been employed for subjects ranging from mathematics [6, 31] and science [32] to language learning [33] and history [34], using games to simplify complex concepts [35], develop creative problem-solving [36], and make learning interactive and engaging [37]. In healthcare, DGBL aids in both professional training and patient rehabilitation, with games designed to improve cognitive and motor skills or simulate medical procedures for training healthcare professionals [38, 39]. In the corporate sector, it's used for skill development and training, offering simulations that replicate real-world challenges [40, 41]. In the military, sophisticated simulations provide training that ranges from tactical decision-making to crisis management [21]. In addition, DGBL may promote public awareness and understanding of particular social topics or issues, such as environmental protection [42, 43]. Furthermore, DGBL has been integrated into programming and computer science education [44]. This wide-ranging applicability of DGBL underscores its potential as a powerful educational tool across various fields, catering to different learning needs and objectives [45], which require educators,

researchers, and developers to take various factors and design elements into consideration in the design and development of DGBL [46].

2.2 Design Principles regarding Game-based Learning

Effective DGBL integrates instructional design and learning theories to create meaningful educational experiences. Central to this approach are key design principles, such as aligning games with specific learning objectives and curricula, thereby ensuring content relevance to student developmental goals [47, 48]. Incorporating scaffolded instruction aids knowledge accumulation, while in-game feedback and assessments facilitate learner self-monitoring [49]. Moreover, embedding learning content into the game's narrative significantly enhances student engagement [50].

Building on this foundation, interactive elements like active learning and inquiry-based approaches are pivotal in facilitating skill development and problem-solving [51, 52]. Diverse gameplay mechanics and social elements, including multiplayer activities, cater to different learning styles and promote social learning [53]. However, design considerations must be tailored to different age groups. For instance, younger learners benefit from engaging narratives and customization options [54], whereas adults respond better to real-world contexts and complex challenges [55]. For children, simplified controls and visually engaging interfaces are crucial [56].

Extending these principles, several key aspects effectively utilize active learning and simulation in games. Interactive gameplay mechanics that allow learners to apply knowledge and skills encourage experiential learning [51]. Immediate feedback mechanisms, such as scoring and level progression, scaffold learning and aid skill development [52]. Additionally, nonlinear challenges with multiple solutions enhance critical thinking and problem-solving skills [47]. while progressively increasing challenge complexity develops competency [50]. Simulating real-world scenarios provides contextual learning [57], and integrating gameplay with debriefing and reflection solidifies knowledge acquisition [58]. Implementing these principles can significantly enhance the effectiveness and engagement level of educational games.

2.3 Positioning the Current Study

The landscape of DGBL research, while rich in studies examining its efficacy across educational settings, reveals a critical gap in the detailed exploration of student engagement principles [10]. Despite the acknowledged importance of engagement for learning, there exists a notable scarcity of large-scale, in-depth studies that gather comprehensive feedback from both instructors and learners [11]. This gap highlights the need for research that not only investigates the cognitive and behavioral outcomes of DGBL but also delves into the qualitative aspects of engagement and design effectiveness [59].

Our review identifies a pivotal research gap: the need for expansive studies on DGBL engagement and design principles. While most of the research, examining the similar topic to us, has been constrained by relatively small participant cohorts, typically ranging from 20 to 200 individuals [60–63], our study distinguishes itself through its large-scale participant base. This methodological approach not only enhances the generalizability of our findings but also provides a unique lens through which the nuanced impacts of game design on student engagement can be examined. In contrast to the traditional focus on cognitive and skill-based outcomes, our study aims to enrich the discourse on DGBL by offering comprehensive insights into how design choices influence learner engagement across diverse learner needs and backgrounds.

3 Methodology

We collected data from more than 1000 middle school students who played MHS. We adopted a mixed-methods approach, intertwining thematic analysis with descriptive statistics. This methodology was deliberately selected to synergize the depth of qualitative insights with the breadth of quantitative contextualization regarding participants' reactions.

3.1 Learning environment: Mission HydroSci

Mission HydroSci (MHS) [12, 13] is a first-person 3D narrative adventure game tailored for middle school instruction in water science and scientific argumentation. This interactive platform is aligned with the Next Generation Science Standards (NGSS), advocating for an innovative science education paradigm that fosters active student engagement with disciplinary core ideas, crosscutting concepts, and scientific practices. Leveraging the "transformational play" pedagogical framework [64], MHS immerses students in a role-play experience where decision-making and actions are informed by academic knowledge, promoting the application of virtual problem-solving to real-world contexts. The game's architecture is further informed by learning progressions research, ensuring a coherent sequencing of educational content and gameplay activities that reflect established trajectories in students' comprehension of water systems [65, 66] and scientific argumentation [67].

MHS is played in six discrete modules, each centered on a specific curriculum topic within water science and scientific argumentation, with a correspondingly themed game map featuring unique landscapes. These modules are meticulously crafted with diverse pedagogical structures and game mechanics to cater to the distinct learning objectives of each topic. The virtual environment is enriched with supplementary learning resources, including animated posters elucidating extraterrestrial technology and the fictional planet's lore, to bolster exploratory learning and enhance student engagement and motivation. In a classroom setting, guided by instructors, students typically complete MHS in 6 to 8 hours.

This duration facilitates adequate exposure to the game's educational content while ensuring retention of the instructional material and allowing for the practical application of learned concepts.

3.2 Participants

The participant cohort of this study comprised 1,110 students, with a gender distribution of 51% male and 49% female. These students were enrolled in the 6th, 7th, and 8th grades, placing their ages between 11 and 14 years. The ethnic composition of the cohort was predominantly Caucasian at 66%, followed by 11% African American, 6% Hispanic, 4% Multi-racial, 3% Asian, and 2% American Indian, while the remaining participants identified as belonging to other ethnic groups. Regarding the educational game MHS, the study garnered 962 responses highlighting positive aspects and 943 responses indicating areas of dissatisfaction. In this paper, we focused on the 943 negative responses.

3.3 Data Collection

This study utilized data from a comprehensive field test of the educational game MHS conducted in the spring of 2019 [68]. The field test involved thirteen science teachers and their classes from nine schools across six districts in a Midwestern state of the United States, aiming to collect evidence-based insights to inform the enhancement of future iterations of MHS. Students participated in the study by engaging with MHS and were subsequently invited to share their feedback through a voluntary online survey administered via Qualtrics. The survey consists of questions with multiple choices and one open-ended question. This open-ended question specifically solicited students' perspectives on the aspects of MHS they liked and those they found lacking. The complete survey information can be found through the link as follow: https://drive.google.com/file/d/1llCFlY4JQXDxPTY9uMRPEMRq3MH7rq4r/view?usp=drive_link.

The primary objective of this data collection effort was to harness detailed, qualitative feedback from the students regarding their experiences with MHS. By focusing on the constructive critiques provided by the participants, the study seeks to identify potential areas for improvement in game design and implementation, thereby contributing to the ongoing development of more engaging and effective educational games.

3.4 Qualitative Data Analysis: Thematic Analysis

In our exploration of students' critical reflections on their experiences with MHS, we conducted a thematic analysis in line with the six-step framework proposed by Braun and

Clarke [69]. Our initial engagement with the data involved comprehensive readings of the participants' feedback, ensuring a deep familiarity with the content. This immersion facilitated the subsequent phase of inductive coding, where we meticulously identified elements within the feedback that were directly relevant to our research objectives. These preliminary codes served as the foundation for the development of broader categories, which were then refined into distinct themes that encapsulated the generalized insights emerging from the data. The evolution of these themes was the result of a collaborative and iterative process, meticulously carried out by a dedicated team of researchers. Each researcher independently engaged in the generation of codes and themes, ensuring a robust analytical approach. To maintain the integrity and consistency of our thematic analysis, we convened regular consensus meetings. These sessions provided a forum for discussing and reconciling any discrepancies in the coding process, thereby reinforcing the analytical rigor of our study.

Addressing the specifics of our coding methodology: Three coders participated in this analytical phase, ensuring a comprehensive coverage of diverse perspectives. To establish inter-rater reliability, an initial subset of the data, representing 20% of the total responses, was independently coded by all three coders. This procedure allowed for the calculation of a Kappa value, a statistical measure of agreement among coders. The analysis of an initial batch of 50 student responses yielded a Kappa value of 0.63, denoting a moderate level of agreement. Subsequent adjustments to our coding framework, informed by in-depth discussions during our consensus meetings, led to a reevaluation of another 50 responses. This reanalysis resulted in an improved Kappa value of 0.74, indicative of a higher degree of interrater reliability and underscoring the enhanced generalizability of our coding scheme. Armed with these refined codes, our research team proceeded to analyze the remainder of the dataset, applying a unified coding framework to ensure analytical consistency across all responses.

3.5 Quantitative Analysis: Descriptive Statistics

Subsequent to thematic analysis, we applied descriptive statistical techniques to quantify the qualitative findings, focusing on the frequencies and percentages of the identified themes. This approach enabled us to assess the prevalence of each theme within the dataset, providing a broad view of the patterns and trends in participant feedback. This way, the qualitative thematic analysis provided in-depth interpretations of the themes, while the quantitative data contextualized the former’s significance within the overall dataset. This combined approach yielded a comprehensive understanding of participant responses, effectively blending the detailed insights of qualitative research with the broader perspective offered by quantitative analysis.

4 Results

Our thematic analysis draws out five main themes: Game Experience, Education and Learning, Graphics, Sound and Interface, Collaboration and Interaction, and a residual category Others. Details about the themes and codes are available by contact with the authors. Considering numerous nonsense comments in the Others theme and the limited number of respondents (only four) involved in the Collaboration and Interaction theme, we do not present any analytic results for those two abstract themes and focus our result reporting on the first three themes.

4.1 Game Experience

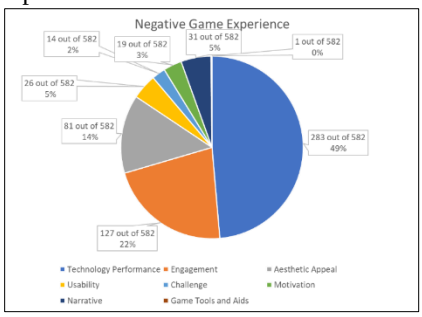
According to Fig. 1, The specific theme - Technical Performance - dominates the negative opinions. The second largest share is held by Engagement. And the third most significant proportion in negative perspectives is attributed to the Aesthetic Appeal.

Specifically, regarding the theme of Technical Performance, negative feedback primarily revolved around game instability, such as lagging, glitching, or freezing. 216 students expressed such negative opinions. Example comments are like, "*Graphics are laughable you can lag 1 time or 50 times depending on something*" and "*The game quality was pretty laggy and slowed down my game play. It had to load a very long time as well and it crashed quite a bit.*" 51 students found the navigation and movement challenging, "*Things I did not like about the game were the directions were very confusing in the alien parts and the game was hard to look around because of the 3D.*" 13 students reported loss of saved data and login issues, "*It kicks u out and you have to start the level you were on and do it over.*" Additionally, 3 students mentioned the occasional disappearance of the mini map caused navigation confusion.

The Engagement theme received the second-highest number of complaints. 52 Students indicated experiencing boredom due to several issues, including erroneous gameplay and repetitive tasks. Furthermore, 32 students reported unclear progress guidance and 33 students mentioned excessive dialogue also negatively impacted the experience, as example comments noted, "*I don't like that the people talk a lot*" and "*It tells you what to do… you don't get the fun of figuring out what to do yourself.*" The left 8 students expressed the need to have more interactivities during the exploration of the game world.

The Aesthetic Appeal theme attracted the third highest number of negative comments. 65 students found the character design unsettling, an example comment is like "*The characters are kinda creepy, the fact that they stand as still as a statue, their eyes are popping out, and they all have the same voice is kinda weird.*" Their comments suggested that our character design might provoke an 'Uncanny Valley' [70] response in some students. 14 participants also expressed a desire for visible and customizable characters, as opposed to a first-person perspective. While 2 students appreciated the game's scenery, they

expressed interest in encountering more wildlife and life forms during their exploration of the open world.



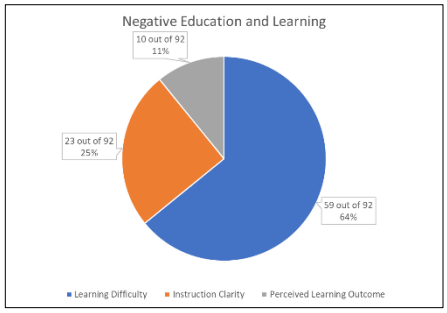


Fig. 1. (Left figure) The pie chart shows the distribution of specific themes under the abstract theme of Game Experience.
Fig. 2. (Right figure) The pie chart shows the distribution of specific themes under the abstract theme of Education and Learning.

4.2 Education and Learning

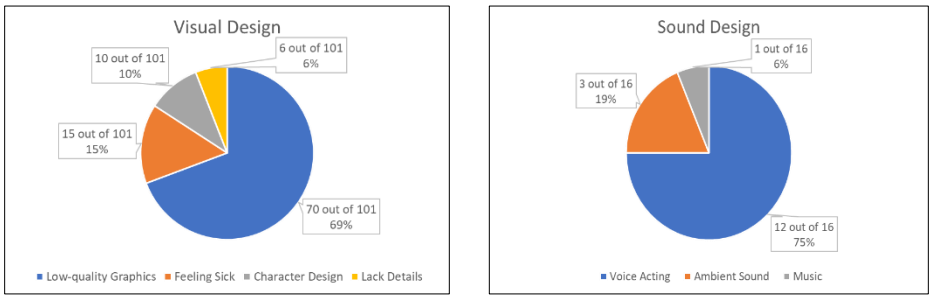
From Fig. 2, we observe that Learning Difficulty garners the most negative feedback. Instruction Clarity stands as the second largest negative category. Lastly, Perceived Learning Outcome is the third most significant theme in the negative feedback.

For the theme of Learning Difficulty, 29 students found the process of constructing arguments to be overly challenging, which, for them, were mainly around the compulsoriness of some reasoning tasks and the inaccuracy of the evidence for the reasoning. For instance, two students commented, "*I did not like when we had to solve the arguments*" and "*I also believe that sometimes the form of arguments you use aren't fitting and things would need more evidence for it to be accurate.*" The increased stress levels while learning certain concepts and a perceived sudden difficulty spike were also concerns for 18 students, "*It was hard for me to understand some things and I got really stressed out sometimes.*" On the other hand, there were 4 students who believed some activities were too simplistic to facilitate engagement, as evidenced by feedback like, "*Some of the puzzles were really easy and didn't interest me.*"

Regarding the theme of Instruction Clarity, 23 students found the instructions too vague, leading to confusion about specific steps and learning objectives. Examples of such feedback include "*Things I don't like about it is that it is hard to understand and know what do. Some things are very simple and I know what do to and other parts I get stuck because there is no instruction*" and "*One last thing I did not like was how they don't really help you out with instructions; they kinda just leave you hanging.*" Additionally, 2 students criticized the lack of review mechanisms for instructions, as one student remarked, "*Sometimes the instructions weren't completely clear and I had to ask for help so maybe include a place where I can look back and see the instructions again.*"

Pertaining to the theme of Perceived Learning Outcome, 13 respondents expressed dissatisfaction, feeling that they had not gained much knowledge from playing the game. 7 students felt that the game was too easy and did not introduce new concepts, as one stated, "*Most of the activities were really easy, and it didn't really teach me anything about science or arguments.*" 5 suggested more practice opportunities for reinforcing learning, as expressed in the comment, "*I feel like I would have learned and gotten more knowledge about making arguments [given more practices].*" Additionally, poor game performance was cited as an impediment to learning, with one student remarking, "*It was very slow and i do not feel like a learned a whole lot.*"

4.3 Graphics, Sound and Interface



A. B.

Fig. 3. The pie charts show the distribution of specific themes of Visual Design (Fig. 3A) and Sound Design (Fig. 3B) under the abstract theme of Graphics, Sound and Interface.

The largest proportion of negative feedback regarding Visual Design (see Fig. 3A) relates to Low-Quality Graphics. 70 Students reported issues such as glitches, lags, and bugs negatively affecting the graphics, with comments such as "*bugs and graphics*" and "*i din't liked the game because the grafica [graphics] were taribal [terrible] and it was very glichy.*" 48 of them noted device limitations prevented high-quality graphic settings, which occasionally impeded game progress, exemplified by comments like "*you cant play in high quality*" and "*I do not like how hard it is to access things and that there is only one point of view for the character.*"

The second highest proportion of negative feedback falls under the Feeling Sick theme, where 15 students reported discomfort due to low-resolution graphics, with comments such as "*We finally figured out that the only way to get the game to remotely work is to turn the quality all the way down, which just hurts your eyes*" and "*the graphics are really bad and it always gives me a headache and makes me dizzy.*"

The third most substantial theme is Character Design, with 10 students describing the characters as unsettling, as evidenced by comments like "*the characters are just creepy and don't look anything like their normally characters on the writing part.*" Lastly, under the

Lack of Detail theme, 6 students lamented the lack of detailed graphics, stating it detracted from their engagement and immersion, with comments such as "*I didn't like that it was so slow and that it wasn't very detailed in the graphics; it was really pixelated and unreal.*"

Regarding the Sound Design theme (see Fig. 3B), the most common complaints pertained to Voice Acting. 12 students were disenchanted by the limited voice variety for characters, negatively impacting their engagement and narrative immersion. For instance, comments include "*It sounds like there are only two people talking for all of the characters and I feel like it would be more enjoyable if they had different voices or accents.*" 4 of them also criticized lengthy dialogues that they found tedious, with one remarking, "*When you are talking to people [in the game], they sometimes have very long paragraphs and I stop really listening because I get uninterested."* Complaints about the slow pace of character speech were also voiced, such as *"I didn't like speed of talking chats.*"

In terms of Ambient Sound, 3 students were irritated by certain background sounds in the game, particularly when accompanied by lags, with comments such as "*The hoverboard and the walking noises are very annoying*" and "*Nothing much besides the grainy sound.*"

Concerning the Music theme, negative opinions were sparse. Just one student considered it a minor issue, "*The music, but that isn't a big problem.*"

To provide a detailed yet concise examination of the feedback areas identified by students, we have organized the findings into a table that categorizes concerns across various themes. This approach facilitates a comprehensive understanding of the core issues impacting student interaction and learning within MHS. Due to space constraints in this publication, the complete table is accessible via an online link provided here: https://shorturl.at/ftBIZ.

5 Discussion

5.1 RQ1: What challenges did students face during gameplay?

Game Experience Insights. Our analysis identified three specific themes in negative feedback concerning MHS: Technical Performance, Engagement, and Aesthetic Appeal. Technical Performance issues, such as game instability, were highlighted by students, who reported frustration with lagging, freezing, and navigational difficulties, as well as lost data and login issues. These issues suggest broader technological and optimization challenges in educational game development, often exacerbated by the diverse quality of devices used in schools, as discussed by [71]. Engagement concerns followed, with repetitive tasks, insufficient progress guidance, and excessive dialogue leading to boredom. Therefore, diverse task types [52] and instant and effective feedback [49] should be provided. The Aesthetic Appeal theme ranked third in negative feedback; critiques pointed to unsettling character designs eliciting 'Uncanny Valley' effects, with a noted preference for third-person visibility and character customization [54].

Education and Learning Understandings. In the Education and Learning section, dissatisfaction spans Learning Difficulty, Instruction Clarity, and Perceived Learning Outcome. Students experienced inconsistent challenges, some finding tasks too difficult for argument construction, while others deemed them overly simple, missing educational depth—a divergence from Kiili and Valenza's expectations. Kucher [72] and McCarthy et al. [73] discuss how adaptive learning mechanisms could align game design with educational goals, enhancing engagement. Ambiguous instructions hindered task completion, with Lodge et al. [74] emphasizing the need for clearer, more intuitive game guidance. For Perceived Learning Outcomes, students felt they gained little knowledge, underscoring van Eck's advocacy [52] for a differentiated learning experience with more complex tasks and additional practice opportunities.

Graphics, Sound and Interface Considerations. In the domains of Graphics, Sound, and Interface, critiques notably focused on low-quality graphics, discomfort from poor visual design, unsatisfactory character design, and subpar voice acting and ambient sound. Key issues included graphics-related glitches, device limitations affecting graphic fidelity, and low-resolution visuals causing physical discomfort. Character design criticisms were linked to unsettling appearances and a lack of detail, reducing engagement. These graphics and sound criticisms highlight potential oversights in user experience testing across different hardware, a challenge also recognized in the broader context of educational game development by Tang et al [75]. Furthermore, negative feedback on sound, particularly monotone voices and lengthy dialogues, underlines the importance of sound quality for engagement, reinforcing Byun and Loh's [76] findings on the impact of sound design on learner engagement.

5.2 RQ2: What design principles can be distilled from student negative perspectives for effective learning game development?

In the ongoing evolution of the game design of MHS, an integrative approach is necessitated to amalgamate feedback from multiple user experience facets—ranging from game mechanics to graphical fidelity and educational content delivery. This synthesis of design principles aims to inform a cohesive blueprint for the enhancement of the game's future versions.

Improving Technical Performance. The first principle is to provide and maintain optimized technical performance and make it consistent and stable across different platforms. In transitioning MHS to a Web GL build, we aim to enhance browser-based playability and increase device compatibility. This approach addresses the challenges of low-resolution graphics and extends gameplay to mobile platforms, thereby broadening access. Inspired by the universal design principles highlighted in [71], which emphasize the importance of cross-platform stability, our strategy includes revamping the game's

aesthetics to a stylized, low-polygon look to reduce hardware demands. Comprehensive device testing and ongoing code optimization are planned to ensure robust technical performance, aligning with the broader goal of facilitating seamless user experiences in educational gaming. Such proactive measures are not only pivotal for the MHS iteration but also reflect a universally applicable strategy in the development of educational games, underscoring the importance of technical reliability for engaging and effective learning environments.

Enhancing Engagement through Diegetic Interactivity. Our second design principle endorses a cohesive integration of interactive storytelling, mission-based gameplay, and pedagogical methods to advance engagement and learning. This combination yields a learning experience that captivates and educates learners within the MHS framework through three primary initiatives:

1. *Narrative and Educational Synergy*. We complemented the main storyline with additional storylines (e.g., side quests or mini games) to support learning objectives, thus enhancing engagement and embedding learning content within the gameplay.
2. *Refined Learning Mechanics.* Utilizing a diegetic approach [77], our game's argumentation system has been redefined to align with situated learning principles [78], thereby deepening immersion. This method embeds learning elements and interfaces directly into the game's narrative. A specific example is to transition the argumentation system from an external interface to in-game debates with non-player characters.
3. *Dynamic Dialogue System.* We maintained learners' learning interest by offering features such as an adjustable dialogue speed and a skip option for diverse learning paces.

The MHS design approach exemplifies a paradigm where gaming and learning are intertwined, creating a dynamic and enriched educational environment. This synergy addresses cognitive, emotional, and behavioral dimensions of engagement, presenting a comprehensive framework for educational game design that marries pedagogical soundness with an immersive gaming experience. Such a framework can be adapted across various digital game-based learning environments, emphasizing the importance of a narrative-centric, immersive educational experience that is pedagogically robust and widely accessible, as also suggested by [79].

Aligning Puzzles with Learning Objectives. Our third principle aims to enhance the educational gameplay through advanced puzzle design, emphasizing cognitive engagement and critical thinking. The game integrates problem-solving within its narrative, aligning puzzles with learning objectives [47, 55]. These puzzles, inspired by generative learning theories [80], require active knowledge application. For example, instead of simply identifying locations on a topographic map, students need to distinguish and predict geological structures, which enhances their understanding of topography. This is supported

by replacing mini-map clues with player-created navigation icons, aiding learning for those who struggle with conventional navigation.

Build Integrated Learning Support and Progress Guidance. The fourth principle focuses on integrating dynamic learning support with clear, diverse progression pathways to enhance learning and reduce repetitiveness. Specific practices include:

1. *Refined In-Game Learning Tools.* Interactive visual aids like 'hard holograms', complemented by user interface enhancements and argumentation mechanics, were modified for high interactivity and visual feedback. The redesign conformed to Mayer's [81] assumptions of the Cognitive Theory of Multimedia Learning. All instructions were tested for comprehensibility, and players had a log system to review instructions, catering to a self-paced learning progress.
2. *Diegetic Framework for Task Progression*. This strategy ensures task progression is seamlessly linked with the narrative, combining explicit instructions with contextual hints. For instance, we are replacing static curricular images with interactive mini-games, thus enriching the in-game educational experience.
3. *Milestone-Based Rewards System.* Implementation of a system setting clear goals (e.g., chapter completion, skill mastery) paired with intellectually engaging puzzles of varying complexity. This method provides a sense of achievement [48] and cognitive progression at each milestone.

Optimizing Aesthetic Appeal and Customization. The fifth design principle is dedicated to enhancing player immersion through visually engaging graphics and advanced avatar customization, which is favored by Valenza et al. [56]. In the upcoming version of MHS, we are shifting towards stylized character designs and moving away from photorealism to avoid the 'Uncanny Valley' effect. This shift prioritizes animated engagement, with a focus on responsive, dynamic interactions over intricate visual details. Key improvements include more vividly animated elements (e.g., the water effect), which aid in puzzle-solving and enhance the player's connection to the game world, thereby enriching the overall gaming experience.

Refining Voice Acting for Emotional Connection. Our final design emphasizes using voice acting to deepen emotional connections in educational game narratives, enhancing gameplay immersion. This approach, applicable beyond the MHS game, aims to boost player engagement and narrative absorption across serious games and digital learning. Key strategies include:

1. *Collaborative Voice Acting for Emotional Resonance*. We engage voice actors in a collaborative process to produce emotionally resonant performances, vital for enriching narratives and strengthening player-character bonds. Authentic emotional expression in

voice acting can make educational narratives more captivating, thereby enhancing learning outcomes. This reflects the importance of emotional engagement in education, supported by research [82, 83].

2. *Efficient and Impactful Dialogue*. We focus on creating dialogue that is concise yet emotionally varied, making voice performances engaging and relevant, and effectively conveying educational content. This approach balances educational and narrative quality, improving learning experiences through emotional engagement and clear communication.

These strategies suggest that incorporating emotional depth into game narratives can make educational games more engaging and effective. Their adaptability across game genres and platforms highlights emotional connection's role in educational technology design, with literature affirming the significance of emotional engagement in enhancing digital learning outcomes [76, 84].

6 Conclusion

To address the identified gap stemming from the lack of in-depth follow-up studies, our research provides a deep analysis drawn from the feedback of over 900 end-users. This feedback, which highlights the "likes" and "dislikes" experienced while engaging with MHS in academic settings, was collected through a mixed-methods approach that directly informs our central research questions. By scrutinizing the specific challenges students face during gameplay (RQ1), we have achieved a more nuanced understanding of the factors that hinder engagement and learning within the MHS environment. Concurrently, the exploration of design principles discerned from students' negative feedback (RQ2) sheds light on how game-based learning environments can be fine-tuned to yield more effective educational experiences. This investigation advances the scholarly dialogue on educational technology and provides a cornerstone for pragmatic enhancements in the creation and execution of educational games. The insights procured from this study are crucial in guiding the trajectory of future game-based learning developments, ensuring they are profoundly influenced by the authentic experiences of learners who navigate their educational paths through these GBL environments.

Acknowledgment. The work described herein is supported by the US Department of Education's Innovation and Research (S411B210031). The ideas expressed do not necessarily reflect the views of the funders.

Thanks to Krista Galyen for their substantial work in collecting, organizing, and early analyzing the data represented in this article.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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