Exploring Mars: An Immersive Survival Game for Planetary Education

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Abstract: Designing educational games can be challenging as fostering academic engagement requires the learning outcomes to be encoded in the game mechanic. Many games that are intended to be educational do not successfully provide this integration and the resulting product can be boring, fail to deliver the learning outcomes, or present the user with periodic interruptions in flow. The aim of this work was to investigate how to design an engaging and effective educational game that teaches the player about planets and their environments. 'Exploring Mars' was designed and built to harbour a player's intrinsic motivation to engage in enquiry-based learning through storytelling in a graphically rich environment with an Artificial Intelligence Non-Player Character (AI NPC). The aim of the NPC is to lead the player through a series of challenges, the solutions to which require them to investigate the planetary environment. In the game, the player assumes the role of an astronaut who has been inadvertently left behind on Mars by their crew following a severe dust storm. The objectives of the game are for the player to navigate the Martian terrain and discover and use essentials —oxygen, food, and energy sources— required for them to survive the Martian environment. The game environment was crafted using Unreal Engine 5 and provides an immersive, visually compelling representation of Mars which is rich in information content. Accompanying sound effects and audio dialogue with the NPC aims to further enhance engagement. The game was evaluated qualitatively through observations and interviews with adult players. Results confirmed that the game's intrinsic gameplay mechanics and immersive environment were successful in imparting the game's learning objectives. Areas for improvement were identified, but the game successfully demonstrates how enquiry-based learning can be fostered through a rich graphical environment that provides the setting for a compelling storyline, with learning scaffolded by AI. The success of the game suggests it could be extended to other planets and used by learners of different ages.

Keywords: Educational game, AI Supported Learning, Enquiry-based Learning, AI Scaffolding, Learning Through Storytelling

1. Introduction

Planetary exploration, and Mars in particular, have fascinated people for hundreds of years and many video games have taken advantage of this, including Surviving Mars, The Technomancer, and Tharsis (Valve, 2024). All of these, however, are designed primarily for entertainment, neglecting the potential to provide an educational experience. A key challenge of educational game development is ensuring that the game is as interesting and engaging as possible whilst effectively integrating its educational components. A high level of engagement by the learner is necessary to provide an effective learning environment (Kalmpourtzis, 2018, p.31) and many do not offer an entertainment experience comparable to that of conventional entertainment video games (Dele-Ajayi et al., 2016). The aim of this work was to create a gamified depiction of Mars, in an educational context, allowing players to experience and learn about the challenges of surviving on the red planet.

2. Background

Intrinsic motivation to learn utilises a player's inherent interest in engaging with the learning activity. It is enhanced through feeling a sense of *autonomy*, *relatedness*, and *competence* (Ryan and Deci, 2000). Autonomy concerns a sense of volition when doing a task; relatedness refers to a player's sense of connection with others and competence relates to feeling capable and effective.

Many game elements can fulfil these factors (Ryan, Rigby and Przybylski, 2006). Open worlds that feel real and aesthetically pleasing facilitate presence (Ryan and Deci, 2017). The incorporation of life-like elements can stimulate enquiry, further developing qualitative understanding (Wang et al., 2018) thus promoting autonomy. Relatedness can be experienced through interactions with others in the game world and advancements in AI now provide for non-playable characters (NPCs) which can participate in meaningful dialogue and display complex emotional reactions (Karaca, Derias and Sarsar, 2024). Ryan and Deci (2017) argue that interactions with NPCs, can promote relatedness, with higher interactivity corresponding to increased relatedness. Competence is enhanced through intuitive controls and environments that provide a balance of challenges that align with the player's growing abilities, enabling a feeling of accomplishment and control (Ryan, Rigby and Przybylski, 2006).

Providing a player with the optimal level of challenge for their skills can lead to flow (Csikszentmihalyi, 1990). Flow motivates individuals to carry out further (learning) activities and increases performance (Engeser and Rheinberg, 2008; Habgood and Ainsworth, 2011). The addition of narrative can further enhance immersion for learners (Jemmali et al., 2018) and motivate learners to initiate and persist in game play, whilst providing scaffolding for problem solving during the game (Adams et al., 2012). However, whilst games can inherently promote flow, traditional educational software often uses games as extrinsic motivators (Habgood and Ainsworth, 2011), where gameplay (and thus flow) is halted, requiring the answer to an educational question before proceeding (Kafai, 1996).

Designing serious games is therefore challenging as it requires integration of the learning outcomes with the game mechanic, with the latter driving intrinsic motivation to play the game (Al-Washmi et al., 2015). Consequently, many serious games fail to deliver their intended learning outcomes (Al-Washmi et al., 2014). Few studies have investigated the pedagogical effectiveness of serious games for planetary exploration and those that have, typically struggled to integrate educational content in a non-disruptive way.

3. Aims and Objectives

The aim of this work was to design, build, and evaluate an immersive and engaging game to teach about planetary exploration using narrative to facilitate enquiry-based learning. The aim was to incorporate constructivist learning, i.e., actively involving learners in constructing knowledge through a "learning-by-doing" situation (Youngblut, 1998). The primary learning objectives are shown in Table 1.

Table 1: Learning Objectives

LO1:	Describe the environment of Mars, namely its climate, terrain, and weather.
LO2:	Understand the hazards and difficulties associated with living on Mars and how these can be managed.
LO3:	Describe prominent technologies used for Mars Exploration.

The game was intended to be an open-world, survival game set on Mars, embodying learning content within the game mechanic to foster intrinsic motivation. Alone on the red planet, players must test their skills of survival and adaptability in a hostile and unforgiving environment. The key game objectives are shown in Table 2.

Table 2: Game Objectives

GO1:	*Exploration*	Allow the player to explore, gather information, and learn about the planet.
GO2:	*Martain Weather*	Simulate the harsh weather conditions of the red planet. The player will have to brave this desert world, its extreme temperatures, and sandstorms.
GO3:	*Health*	Allow the player to manage their oxygen levels, food, water, and body temperature.
GO4:	*Missions*	Provide the players with missions and the ability to conduct scientific research.

Players will construct knowledge through enquiry-based problem solving in the game. With this constructivist approach, players formulate hypotheses and test them through observation and experimentation (Pedaste et al., 2015). An AI-powered NPC, 'Cosmo', will act as a robotic helper, offering guided assistance and scaffolding to players throughout the game. This character, integral to the narrative, will engage players in direct conversation, providing instructions, posing story-driven questions and offering a channel for players to inquire and learn.

4. Methodology

A faithful Mars environment, with special consideration to its properties, atmosphere, and visual aesthetics was designed to naturally encourage players to assimilate information about the planet. The game was developed through Unreal Engine 5 (UE5), chiefly due to its exceptional graphical capabilities including photorealistic rendering (Pokorný and Zapletal, 2021).

The game was designed for players to progress via interconnected missions, with successful completion of one unlocking the next. The game was primarily programmed with Unreal Engine's Blueprint visual scripting language, as it allowed for faster prototyping and iteration, although some elements were coded with C++. In-game terrain was derived from high-resolution Mars satellite data (The University of Arizona, 2022). An AI NPC (Cosmo) was developed through a combination of technologies used to simulate conversational interactions with the player. Dialogue generation and interaction capabilities were powered by the GPT API Turbo 3.5 model (OpenAI, 2023), enabling contextually appropriate and dynamic responses with minimal latency. Azure's Text-to-Speech (TTS) service (Microsoft, 2024) was employed to synthesize Cosmo's voice, with further UE5 processing applied in-game, and speech recognition is based on a high-performance inference of OpenAI’s Whisper model (OpenAI, 2022; Treshchev, 2023), running locally.

The game was evaluated through player observations and interviews to determine gameplay experience, engagement and changes in knowledge from playing the game.

5. Game Design

5.1 Landscape Design

Creating the in-game terrain was an iterative process that involved experimenting with several methods. The initial landscape design used Unreal’s Landmass plugin but proved too uniform. Terrain software, TerreSculptor was subsequently used to generate more complex and procedurally generated terrains. However, these failed to capture the geography of Mars. Therefore, the final landscape design was created through Digital Terrain Models (DTMs) produced through HiRISE (University of Arizona, 2022), a high-resolution camera orbiting Mars. Elevation data from three distinct Martian regions—'Landforms in Utopia Planitia’, ‘Youthful Crater and Ejecta’, and the ‘Grand Canyon of Gale Crater’—were amalgamated into a single, expansive heightmap. This composite heightmap was imported into UE5 and further refined including sculpting cliffs around the perimeter to serve as natural barriers, delineating clear boundaries for players to navigate within (Figure 1a). Following this, the sky, materials, 3D assets, and post-processes were configured, resulting in a visually immersive environment (Figure 1b).

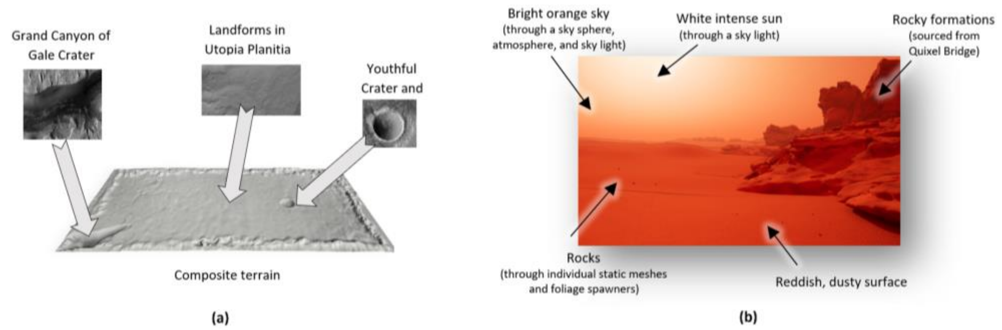


Figure 1: (a) Composite terrain produced through DTMs, (b) in-game perspective on the surface of the terrain

5.2 Character Design

Players can control their in-game astronaut character, through a first-person or third-person perspective. The game’s controls are mapped to familiar schemes for either keyboard/mouse or controller input to ensure intuitive control, thus increasing the sense of *competence*. Careful consideration was given to seamlessly integrating the character into the world to create a ‘learning-by-being-there’ experience, promoting active learning through interaction, uncertainty and choice in the environment (Dengel and Mägdefrau, 2019, p.1). Environmental presentation and interaction (Figure 2) contribute to this. Haptic feedback through the controller aimed to enhance immersion and awareness of in-game surroundings (Söderström et al., 2022) and audio effects such as footsteps added to this. Fluid animations were implemented to convey the low gravity on Mars.

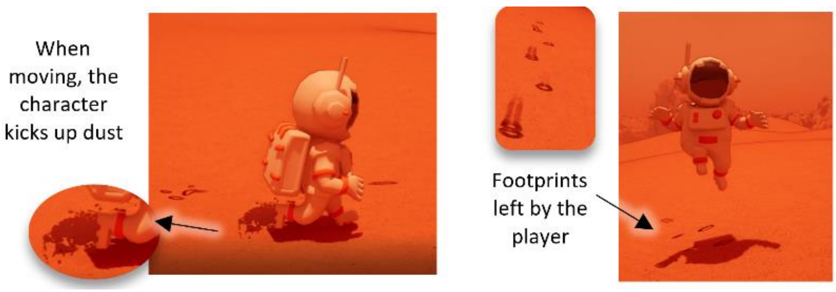


Figure 2: Player character and environmental interaction

5.3 Cosmo NPC Design

Cosmo is a form of chatbot aimed to foster a sense of *relatedness*. The educational benefits of chatbots are many, including keeping learners motivated, engaged and being able to provide immediate assistance and tailored information (Okonkwo and Ade-Ibijola, 2021). However, their use as an NPC in this context has only been briefly explored (Hollister, 2024).

Players communicate with Cosmo via their microphone or keyboard and can form a connection through personalised dialogue, effectively building a para-social relationship with the AI (Namburi and Hopkins, 2023). This can elicit emotion in the player which is key for engagement and learning (Gallego-Durán et al., 2019). Cosmo exhibits a range of facial expressions aimed to make it appear more 'life-like' and relatable, and thus more likely to create the illusion that the NPC is 'alive' in some sense (Lim et al., 2012). Moreover, providing the player with volition to dictate their dialogue to Cosmo enhances their sense of *autonomy*, as they can direct the conversation according to their interests, shaping their own learning experience. Cosmo is also equipped with hard-coded responses that are triggered by specific events within the game, ensuring that essential narrative elements are delivered. For instance, Figure 3 illustrates Cosmo's programmed response through a custom Blueprint Node after a dust storm, querying the player's experience upon re-entering the base.

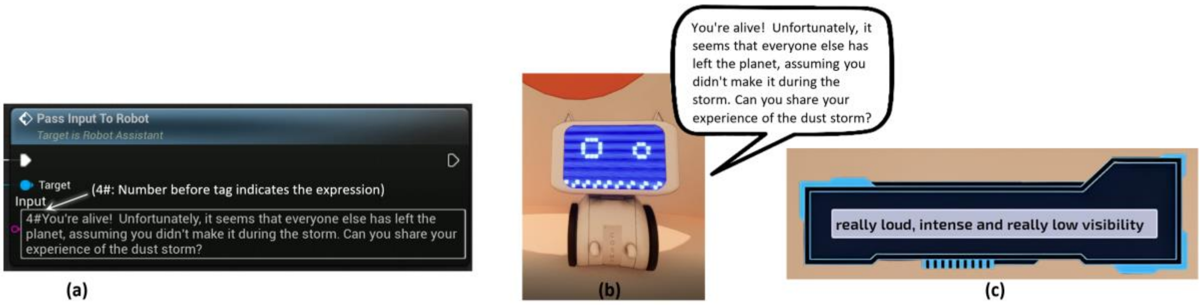


Figure 3: (a) Passing input to robot when the player reaches the base (custom text input, Fig 5), (b) robot talking to the player (with surprised expression) (c) exemplar player response through their keyboard in the chat box

Importantly, Cosmo provides feedback to the user (Gallego-Durán et al., 2019) indicating when an input is being processed, ensuring visibility of system status (Nielsen, 1994). Figure 4 provides a high-level flowchart of Cosmo's communication.

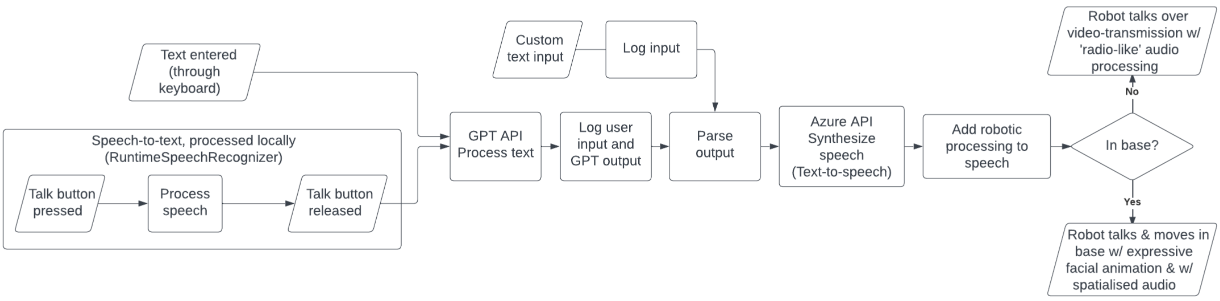


Figure 4: High-level flowchart detailing input/output for Cosmo

6. Gameplay Implementation

6.1 Prelude

A four-minute prelude creates the narrative for why the player is stranded on Mars. The player finds themselves caught in a dust storm, with an approaching dust cloud, including depictions of reduced sunlight, limited visibility, dust particles, and powerful winds. This serves as an attention-grabbing introduction to the game and introduces some of the game mechanics (Figure 5).

Figure 5: Annotated gameplay from the game prelude

The player is introduced to the 'scanner', which allows players to investigate and gather information about the environment. They are then directed to navigate through the storm and regroup with their crew who communicate to the player through synthesized audio 'voice-acting' generated through Replica Studios (2023). Drawing inspiration from the film 'The Martian' (2015), once the player nears the crew, a scripted event is triggered where a satellite dish rips free and hits the protagonist. Chatter can then be heard over the radio about the decision to leave the player behind, who witnesses the rocket taking off and leaving the planet. The screen fades to black as the dust storm has passed and the character picks themself up from the ground (Figure 6).

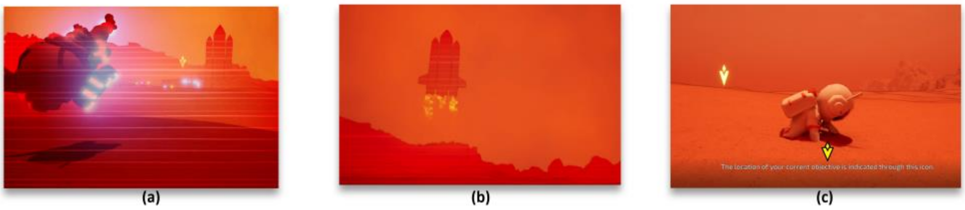


Figure 6: (a) Player's character colliding with a satellite dish and being "rag-dolled" backwards (visual, haptic and audio effects featured) (b) rocket leaving the player behind (c) character recovering after the storm

6.2 Stage One—Dust Storm and Oxygen

Given their low oxygen levels, the player needs to return to base (Figure 7) where they are greeted by Cosmo, who explains the character's in-game situation and asks about their experience during the storm. Cosmo discusses the environment, guiding the player to replenish their oxygen supply so that they may venture outside.

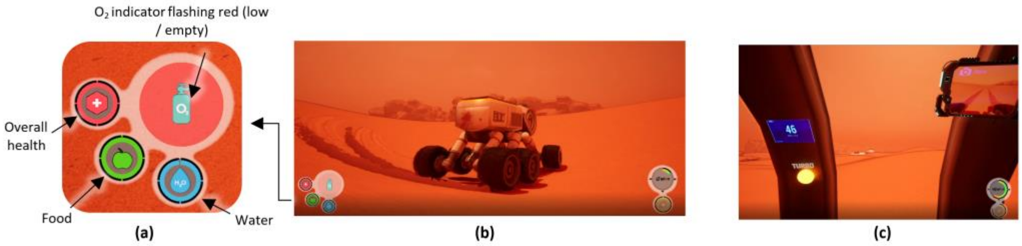


Figure 7: (a) Survival Essentials UI (b) third-person gameplay of the rover (c) first-person gameplay of the rover

6.3 Stage Two—Food

The game moves towards the topic of acquiring food through a structured enquiry-based learning activity (Zion and Mendelovici, 2012). The player is posed with an initial question: "You need food, what do you think would happen if we tried to grow plants outside in the Martian soil?" Following a discussion, the player utilises the scanner to investigate the composition of the soil, before reaching a conclusion (Figure 8). Cosmo then suggests checking inside the base for remaining food brought from Earth.

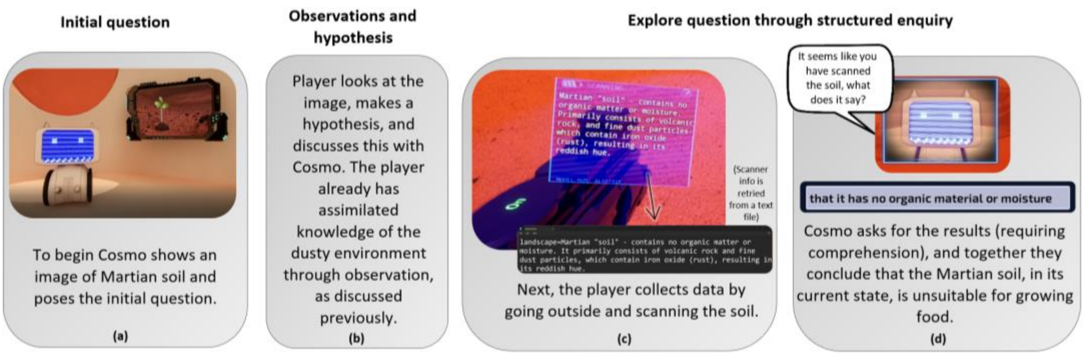


Figure 8 (a)-(d) Player following a structured enquiry

Pointing the scanner at objects predominantly relies upon a 'line-trace' to determine which object is being pointed at, and then retrieves the relevant information in a modular approach by reading it from a text file as shown in Figure 8(c). The scanner enables game progression, but it also empowers players to quell their curiosity and actively seek knowledge; encouraging self-driven exploration and discovery. Players are also encouraged to talk with Cosmo for any potential learning enquiries.

6.4 Stage Three—Energy

In attempting to access a room to check for food the player discovers a problem with the power source (Figure 9a). Cosmo prompts the user to consider where power is obtained on Mars, nudging the player's focus to recent events: "remember the dust storm and all those sand particles blowing around? Do you think they might have interfered with the solar panels?" This creates a meaningful connection to the player's earlier experience of the storm, setting up a logical bridge towards the dusty condition of the panels. The player now needs to locate the panels, determine the issue (the dust storm has covered the panels – Figure 9b), and report back to Cosmo.

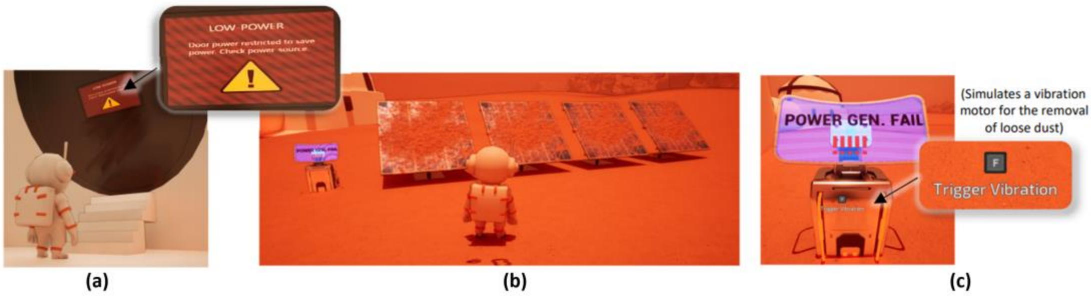


Figure 9: (a) Player encounters power-restricted area, (b) dust-covered solar panels, (c) control box displaying power generation problems

Once reported, Cosmo informs the player on how to clean the panels (Figure 9c) resulting in power generation visibly returning to normal. This scenario aims to result in 'meaningful play'; making relationships between actions and their outcomes discernible and integrated into the larger narrative of the game (Salen and Zimmerman, 2004, p.47). In this instance, the need to restore power connects directly to the survival of the player, thereby effectively integrating the learning process into the gameplay. The player is now able to access the room to replenish their food levels.

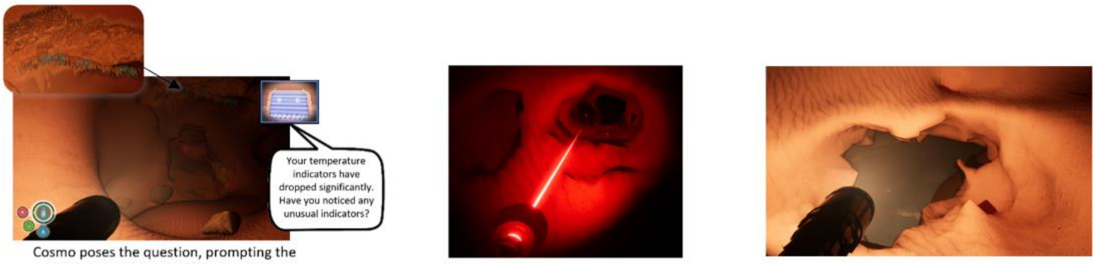
6.5 Stage Four—Underground Cave

The game narrative shifts towards exploration where the player is encouraged to venture into the underground cave with an open-ended and 'non-controlling instruction' to explore (Figure 10), capitalising on the player's desire for *autonomy*. Strategically positioned triggers activate Cosmo's communication over video transmissions. For example, on reaching the cave entrance, Cosmo informs players about the origins of the cave formations—products of ancient lava flows; serving not just as an informational tool, but as a companion in the cave, enhancing the player's sense of *relatedness*.

(a) (b) (c)

Figure 10: (a) The rover parked next to the crater leading to the cave, (b) the underground cave entrance, (c) example mineral being scanned by player

Eventually, as the player ventures deeper into the cave, Cosmo prompts the user to observe their environment and use a laser drill to 'dig' underground (Figure 11b). The discovery of an expansive subterranean deposit of frozen carbon dioxide and water ice leads to a discussion of the implications this might have for further colonisation efforts.



Cosmo poses the question, prompting the player to observe their environment.
(a) (b) (c)

Figure 11: (a) Player's handheld torch illuminating the cave, (b) player's laser drill carving deeper into the ground, (c) hole created by the laser revealing water ice

7. Evaluation

Four Computer Science third-year undergraduates, all aged in their early 20s, were recruited using convenience sampling, for a preliminary evaluation (online and in-person) in October 2023. Players were observed playing the game. Pre- and post-interviews (10 minutes each) were conducted which asked participants questions related to each of the game's learning outcomes (LO1-3). Specifically, the interviews focused on participants' knowledge of the landscape, climate, terrain, gravity, potential hazards and technologies that have been used on Mars. Gameplay was recorded to observe player behaviour and understand levels of engagement with the game outcomes (GO1-4). Table 3 shows the findings in relation to learning outcomes.

Table 3: Degree to which the game Learning Objectives (LO) were met

Player	Pre-gameplay Knowledge	Observations	Post-gameplay Knowledge
A	Substantial understanding, able to correctly answer all pre-gameplay questions, covering each LO (1-3).	Played for 20 minutes. Complimented visual effects, and value of the game as an interactive learning tool for younger players or those less familiar with Mars. Found Cosmo entertaining.	Acknowledged discovering new information about Mars' terrain and atmosphere (LO1).
B	Some prior knowledge, some misconceptions for each LO.	Played for 40 minutes. Approved of visual effects. Stated the game helped correct/expand knowledge of Mars.	Knowledge around LO1 and LO2 greatly improved, less with LO3.
C	No prior knowledge of any LOs.	Played for 60 minutes. Described game as more engaging than reading about Mars, found Cosmo fascinating.	Increased knowledge around all LOs.
D	Many misconceptions about Mars (all LOs).	Played for 30 minutes before their system crashed.	Volunteered extensive feedback on what they had learned, indicating all LOs had been met.

7.1 Observations

Participants A, B and D showed approval of the game's visual presentation. Participant A complimented the game's atmosphere remarking on 'cool effects and lighting'. He 'liked the terrain backdrop', stating it was 'a bit bare' but that it 'reflects Mars well' (LO1). Participant D reported, 'I learned that there are lots of hilly surfaces as depicted […] I noticed this especially when walking at the beginning up lots of hills and it was a slow trek' (LO1), making reference to the game's prelude, but also suggesting a level of immersion. He noted to grow food, 'they may have to use something called hydroponics', but that he was 'not sure what that is' (LO2).

Participant A highlighted the experience with Cosmo as particularly entertaining and 'an engaging way to learn', with the Martian environment and graphics acting as a catalyst to stimulate enquiry, and Cosmo being reported as 'useful for answering questions about the environment' (LO1). The participant observed, 'no games really use that [AI NPC]', 'it'd be sick [sic] in games because it means expanded dialogue and storylines', highlighting the technology's potential benefits in increasing *relatedness.* Participant B commented, 'I was genuinely impressed by the Cosmo part and it works well with the educational aspect of the game'. He praised the relevancy and contextual nature of Cosmo's responses. He had much fun talking to Cosmo (Figure 12), humorously noting, 'I learnt that you can't get a TV signal on Mars' following a discussion on what astronauts can do for entertainment on Mars. He often asked whimsical questions about aliens and other topics, seemingly entertained by Cosmo's engaging (yet educational) responses.

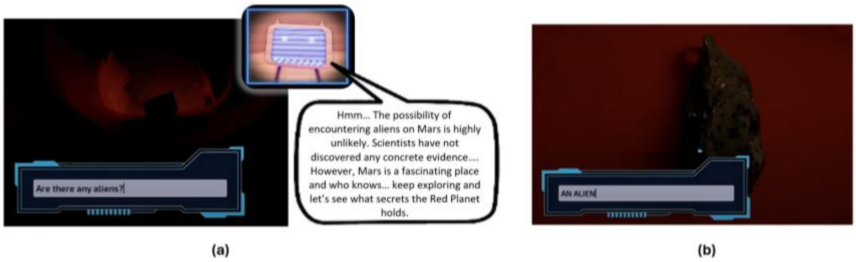


Figure 12: (a) The player enquiring if there are any aliens in the cave accompanied by Cosmo's response, (b) the player humorously claiming to have discovered an alien while examining an intriguing rock

It is evident Participant B also felt a sense of connection to Cosmo, often imbuing it with human-like qualities with phrases such as 'I'm coming' when heading back to base and bidding Cosmo farewell upon leaving. These underscored the player's immersion within the game but also suggested that the game effectively engaged the player's intrinsic need for *relatedness*. However, the participant's recall of educational content still had gaps; when questioned on the Mars InSight lander explained by Cosmo through the screen inside the base, he responded, 'I probably zoned out for that bit' (LO3). He added, 'the screen isn't really used for anything gameplay-wise so you don't look at it a whole lot', suggesting a lack of engagement with this element as it wasn't integrated directly into any mechanic or central narrative of the game. He did, however, praise the integrated learning content, 'I liked how it implemented the hunger/oxygen/water systems into what was actually needed to survive on Mars' (LO2) and he liked the scanning task with its conveyance of knowledge.

Participant C found Cosmo fascinating, impressive and repeatedly asked how it worked. He would have liked subtitles for Cosmo's dialogue to help him absorb information more effectively and minimise in-game distractions. Notably, at the end, he spent a considerable duration simply conversing with Cosmo; however, as the interactions progressed, he veered off topic, broaching topics extraneous to the Martian context, such as queries pertaining to Egypt. This highlights the need for refining Cosmo's design, introducing mechanisms to confine its responses within the game's thematic boundaries.

7.2 Summary

The learning outcomes were met to different extents by different participants. All demonstrated greater knowledge after the gameplay with respect to LO1, including participant A who had considerable prior knowledge. Participant B had increased knowledge around LO1/2, but less so with LO3 having 'zoned out'. Participants C and D both demonstrated increased knowledge around all LOs, post-gameplay. LOs were met not solely from explicitly designed educational components, but predominantly through engagement with the game's visual presentation and interaction with the game's environment. Players described their experiences with enthusiasm and conveyed details in a manner that suggested Mars was somewhere they had 'visited'.

8. Discussion

Exploring Mars provided an immersive, interactive, graphically-rich environment with an AI NPC that guided the players through a narrative motivating them to explore (GO1) and engage in missions (GO4) where they were able to gain knowledge about the Martian weather (GO2) and managing their own health needs (GO3).

During the evaluation, all participants provided evidence that the primary learning objectives of the game had been met, albeit to different extents, with detailed recollections of the environment, its challenges and their problem-solving experiences. Some had expressed surprise at the Martian environment with many preconceptions corrected through the gameplay (LO1). There were several comments regarding the hazards and difficulties of living on Mars and how these could be managed (LO2). There were also comments on technologies for Mars exploration (LO3), but less knowledge was gleaned about some of these such as the Mars InSight lander.

Designing for discovery is difficult. New content needs to scaffold onto already discovered content at a rate that keeps the player in a state of flow (Gallego-Durán et al., 2019). Intrinsic motivation to explore and engage with the learning outcomes was fostered by the AI NPC which engaged the players, imparting information to them and guiding them through the environment and narrative. *Relatedness* with this character was strong, with one player joking with the NPC and another moving on to ask about unrelated topics, which also demonstrated that player's sense of *autonomy*. Dialogue with the NPC was meaningful (Karaca, Derias and Sarsar, 2024), with players recalling situations and interactions with Cosmo, evidencing their feeling of *relatedness*. Players engaged with exploration of the Martian environment for a considerable period. One player stated they knew a lot about Mars, but still explored for 20 minutes. The others explored for longer, demonstrating their sense of *autonomy*. Players were scaffolded by Cosmo to solve problems. They overcame challenges demonstrating a sense of achievement and *competence*, having understood the reason behind challenges and how to overcome them. Their *competence* was enhanced further by the activities they were engaged in such as scanning and digging.

The graphically realistic environment with its audio and haptic feedback enhanced immersion. The addition of a game narrative and AI NPC which promoted constructivist, enquiry-based learning meant that players were intrinsically motivated to engage with the gameplay and hence the encoded learning outcomes. Their sense of *autonomy*, *competence* and *relatedness* was apparent from their reactions to the game and their comments regarding the knowledge they had gained demonstrated that the game had successfully imparted the learning outcomes. Intrinsic motivation had also maintained their state of flow while playing, which was particularly evident from one player who spent a considerable amount of time conversing with Cosmo.

9. Conclusion and Future Work

Overall, the game conveyed a realistic, immersive Martian environment which met the intended learning outcomes. Narrative, problem-solving and contextual enquiry were key to this. The use of an AI NPC significantly enhanced the narrative and engaged the player through relatedness whilst scaffolding their ability to gain competence and autonomy. The game intrinsically motivated players to engage in the learning content.

Future developments include extending the game to other planets and providing subtitles for Cosmo's dialogue to help players to focus and absorb information, enhancing inclusivity. A more comprehensive evaluation, including with children, needs to be done, but restricting Cosmo to relevant discussion topics would be important for safeguarding. The evaluation, whilst preliminary, has already shown a valuable contribution to the area of games-based learning through the development of an intrinsically motivating educational game. The aim of promoting constructivist, enquiry-based learning through narrative and scaffolding, utilising intrinsic motivation has been successfully met.

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