Enter the Backrooms of *Tattva Bhoomi*: An Educational Game for Middle School Students in India

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Abstract

This paper outlines the development process of *Tattva Bhoomi*, a game-based learning application developed by the authors and designed to teach chemistry concepts to middle school students in India. The paper begins with an overview of the design considerations that guided the game's development. Additionally, the paper elaborates on the iterative creation of prototypes at different phases and how gradual improvements were integrated. After providing a walkthrough of the entire gameplay, *Tattva Bhoomi's* potential is assessed using the criteria established by Solanki and Mathew (2021) for the efficient development of educational and multimedia games.

Keywords

Game design; game design for learning; game-based learning; Indian education.

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Introduction

Games, game-based applications, and game-based learning environments have been found to be useful for teaching and learning in schools (Barros et al., 2019; Bressler et al., 2019; Briscoe et al., 2018; Kim & Pavlov, 2019; Rose et al., 2020). However, scholars such as Bennerstedt (2013) have also pointed out the difficulties of knowledge transference through game-based modalities. There are observations in the literature that resonate with the problem of knowledge transference for any activity that might be unfamiliar to learners, with authors noting that a skill learned through games does not always translate into a skill in real life (Bennerstedt, 2013). The literature that sheds light on the impact of games on teaching and learning is generally conducted in, and focused on, Western countries (Cassell & Jenkins, 2000; Ghuman & Griffiths, 2012; Iftikhar et al., 2008). There is an evident lacuna in the literature on games and learning, specifically about India.

Therefore, this study presents an overview of *Tattva Bhoomi* (Land of Elements, in English), a first-person exploration-based game that was used to test the learning of middle school children in India for short-term knowledge retention. To assess the effects on short-term knowledge retention, this game was tested through a pilot study, and it was observed that 37 out of 38 students showed improvements in their post-test performance (Solanki & Mathew, 2022).

Development of *Tattva Bhoomi*

This section outlines the design of game components in *Tattva Bhoomi* in relation to the game's functional requirements. For the purposes of this study, it was pertinent to employ a game genre that was appropriate for the target demographic, Indian middle-school students. In terms of graphics, the two options were to develop either a 2D or 3D game, and in terms of player perspective, the options were to choose either a first-person or a third-person perspective. After adopting Unity as the game engine, the researchers chose to build a 3D game with a third-person perspective, and the entire design of the game was done by Chaitanya Solanki (CS). The choice to adopt a 3D first-person gameplay style was taken to give the player a more immersive experience (Denisova & Cairns, 2015). Since the intention was to create a game that all participants could play on their own devices, it was important to use graphics and game assets that did not require computationally intensive machines. This was because some participants would have less powerful computers, and the intention was to run the game on computers available to as many students as possible. For this reason, a balance was struck between good graphics and maximum access of playability on all types of computers. The researcher employed a second laptop (in addition to the original computer

on which the game was designed) with significantly low specifications to test each game iteration. If the game ran smoothly on a low-specifications laptop, it was considered good enough to ensure playability on many different computers.

An initial decision was made to ensure that user interaction and exploration within the game should be kept simple to accommodate users who were inexperienced with games. For this reason, the game was navigated using keyboard and mouse, while the player's interactions with the 3D game objects were triggered simply by approaching them, without requiring clicking or to press any keys. For ease of development, the research was limited the detailed development of one landscape (also referred to as "game level") and asking users whether they would prefer more game levels in a future expansion of the game. Initially, three levels were being developed simultaneously, but it was found that all of them lacked visual and gameplay details due to time and resource constraints. Therefore, building a single level in greater detail was decided on, while the others were saved for future development. This particular level consisted of a landscape that sought to mimic the topography and terrain of Rajasthan, a state in India with desert-like features. The gameplay would consist of the player exploring the landscape, looking for items to collect.

The 3D game objects were developed as 3D model assets in Blender, then shaded and texturized in Materialize. The level contained large and small rocks that players could climb during exploration. Some of the big rocks were placed so that they would gradually guide the player towards mini-goals of the game, such as obtaining scrolls and mineral ores. The landscape was also populated with dry, barren trees, and shrubbery, and the occasional cacti broke the monotony of sand. The terrain was uneven, imitating the dunes of Rajasthan, and there appeared to be dry winds, evidenced by flying sand particles.

Sound Design

Tattva Bhoomi employs looping background music that is different for each playable level (three levels in Rajasthan). The assortment of music was selected for its Indian musical aesthetics, with the first level featuring a tune played on the Rajasthani instrument called iktara. Initially, the music was the same for all levels, but this led to a monotonous gameplay, so it was decided that different musical pieces would be used for each subsequent level.

A range of sound pieces are associated with certain interactions. For example, when the player interacts with a scroll, a small paper crunching sound is emitted. When the player approaches and interacts with the elemental ores, various metallic sound pieces are pinged. These sounds are

intended to reinforce the idea that an interaction has taken place and are meant to enliven the gaming experience.

Interface

The interface of this first-person game is composed of two graphic icons and other interactive pop-ups. These make up the entirety of the heads-up display (HUD). First, in the top right corner, there are text pieces that read "Ores Collected (Total 20):0" and "Scrolls Collected (Total 4):0." These are the first pieces of information the player gets within a playable level; they are designed to let the player know that they need to collect 20 ores and 4 scrolls. The zeroes within the text change as the player interacts with a scroll or picks up an ore, indicating that the player is headed in the right direction and playing the game as intended.

The bottom left corner contains five icons representing different keyboard buttons. The first icon reads WASD and is accompanied by the text "Movement." The SHIFT icon is accompanied by the text "Sprint," the text "Crouch" is next to the CTRL icon, and "Jump" is written near the SPACE icon. These are all informational nuggets placed to constantly remind and inform the player of the navigation buttons. Other pop-up interfaces are described below, along with the objects that trigger their interactions.

Navigation

The dedicated WASD, spacebar, CTRL, and SHIFT keys allow the user to walk, sprint, jump, and crouch in any direction. The game features encoded head bobbing and minor swaying to mimic real-life first-person movements while walking and running to increase immersion. Players can traverse the entire landscape at their own pace and comfort. If the player reaches the edge of the playable area, they collide with an invisible wall that stops them from going further and presents them with a prompt that reads: "This area has not been unlocked yet." This is intended to encourage the player to turn back and motivate them to unlock more playable areas in the future. As it will be pointed out further in the subsections below, the navigation capabilities of the player change with the levels they complete.

Scrolls

The scrolls are game objects that resemble rolled-up paper. They are scattered throughout each level, sometimes half buried in the sand, and one of the main goals of the game is to search for and find them all. Interaction with a scroll is triggered when the player approaches it and is within touching distance. A scorekeeping text is placed on the right-hand top corner and indicates the number of scrolls and ores that the player has collected. Upon triggering (and collecting) a scroll, an image pops up and reveals an unravelled piece of parchment that displays the contents within the scroll. The player can spend as much time as they want reading it, and

once they are satisfied with what they have read, they can move away from the scroll, and the image disappears; along with it, the scroll asset is also destroyed. This is done so that the player can pick up each scroll only once. To make it easier for the scrolls to be seen within such a huge landscape, subtle spotlights were added on top of them, which made them stand out among the yellow desert landscapes. This decision was made because the landscape was relatively large and visual indicators helped highlight objects of interest to the player.

Scrolls serve many purposes and significantly improve the game. The first scroll the player interacts with is designed to let the user know of the location where they are physically placed within India, which for the first level is the Zawar mines of Udaipur (see Figure 1). It informs the player of several minerals and ores found in these mines and throughout Rajasthan. Finally, the image informs the player of the need to collect all the scrolls and ores in the landscape if they want to proceed to the next level.

Figure 1. Contents of the first unravelled scroll that the player interacts with. Scroll designed by authors.

The scrolls found later in the game inform the player in detail about the elements found in the Zawar mines and which ores they belong to. Zinc and silver were chosen as the periodic elements for this game because they are actually found in the Zawar mines of Rajasthan. The scrolls also describe the physical and chemical properties of these elements and their locations in the periodic table, as well as highlighting the key uses of these elements.

The information contained within the scrolls of the last level of the game moves away from element descriptions and focuses instead on the block distributions of elements in the periodic table and why the classification of elements is necessary and done in the first place. The gradual change in the information distribution within these scrolls was designed so that the player first reads about the game objects with which they interact—the ores and elements—and then correlates that to the process of classifying elements and why that classification is important.

Metal Ores

The second important game object that the player needs to collect to progress within the game is metal ore. As the game has been designed to represent only the details and properties of zinc and silver, the level is populated with two types of ore clusters. The first is silver in colour and metallic in texture. It represents the ore galena, which is commonly found in the Zawar mines and is regularly used to extract silver metal. The second consists of maroon-coloured rocky clusters representing sphalerite, the ore used for zinc harvesting.

Every time the player approaches and collects the metal by walking over it, a pop-up text reads "Galena Collected!" or "Sphalerite Collected!," accompanied by a metallic pinging sound. These feedback interactions are placed such that the player is certain that a metal ore has been collected. It was also decided to make the collection mechanism simple for better playability; therefore, the approach-and-collect method was adopted, rather than requiring the player to click to pick up the metal. Only when the player has collected all the ores and scrolls of the current level will they move on to the next one.

Walkthrough of *Tattva Bhoomi*

The game development software unit exports a directly playable executable file that does not require installation.

Title Screen

The game opens with a title page consisting of the heading "Tattva Bhoomi" and a few options that allow the user to continue, change the volume, or quit the game (see Figure 2). Since the page is intended to familiarize the player with the game setting they are about to experience, it is composed of a text box that contains descriptions of the gameplay ahead. The body of the text describes the various geographical terrains of India that the player can expect to visit and paints a mental picture of the different landscapes within the country. It also informs the player that all of the landscapes contain some sort of natural resource, and illustrates some of the elements of the periodic table that may be discovered at these respective sites. The text box ends with a line asking the player: "Would you be the courageous

explorer that this journey beckons?" This statement aims to further immerse the player in the world of *Tattva Bhoomi* and give them hope for the discoveries within. After pressing the "Play" button, the player is led to the next screen.

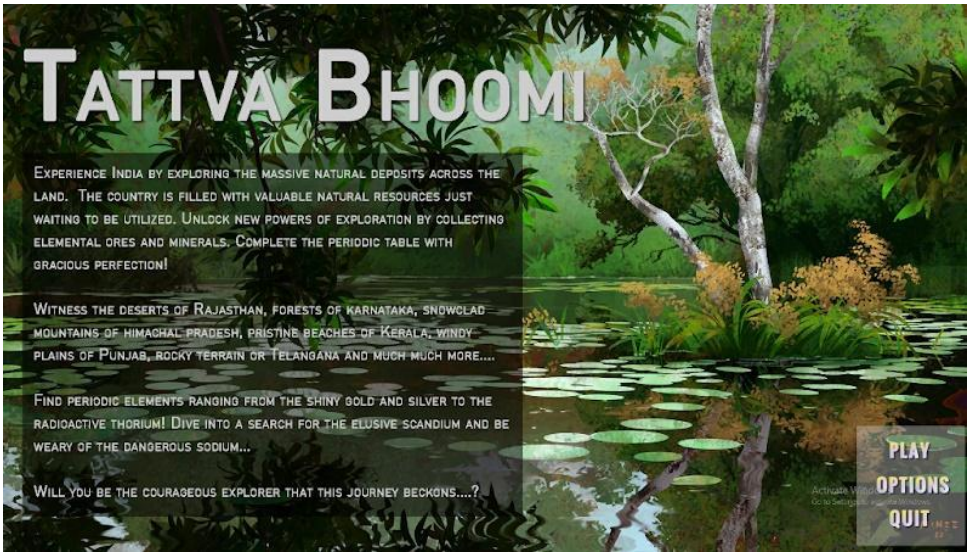

Figure 2. The title screen of *Tattva Bhoomi* briefly describes the game ahead. Screenshot from the game taken by the authors.

Landscape Selection

The second scene depicts a topographical map of India (see Figure 3). Although the map is not very detailed, the image is intended to have the player instinctively associate different parts of India with different types of terrain, ranging from a concentration of mountains in the north to deserts and coastal green hills as one proceeds further south. The map is dotted in 36 different locations, and each of these dots indicate one state or union territory (UT) in India. And while learning 36 names at once is a difficult task for anyone, the game aims to inform the player about the various states and UTs within India through repetitive reinforcement as the player sees this screen every time they play the game. There are 28 states and 8 UTs in India as of 2024, and the researchers wanted the player to realize that some of the dots on the map are not states but UTs. Therefore, it was decided that the name of the UTs would be marked with a symbol to distinguish them. A white circle is placed next to the name of each UT, but there is no explanation anywhere of what the circle means, as this study also aimed to observe whether the players would question this design decision and be curious to learn what it meant.

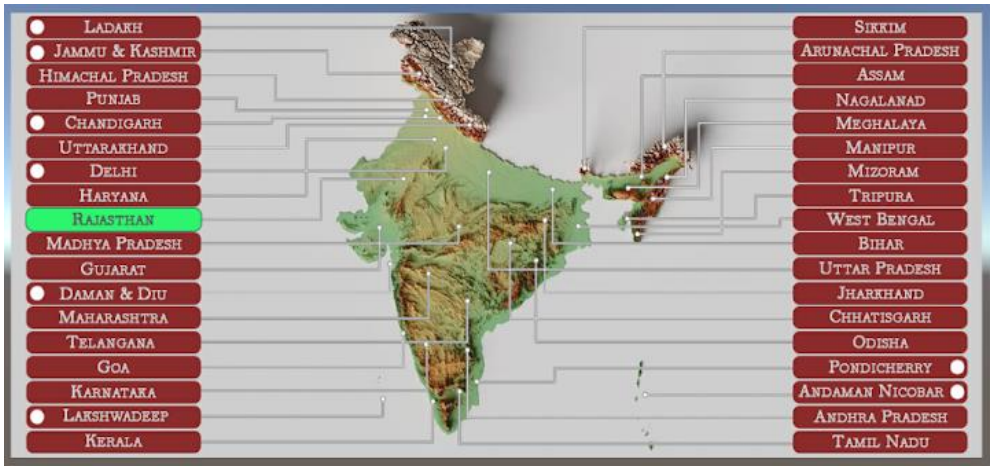

Figure 3. A topographical map depicts the 28 states and the 8 union territories of India. Screenshot from the game taken by the authors.

Of the 36 names, only one name is interactive: the state of Rajasthan. The interaction is designed so that the button with Rajasthan written on it changes colour when the player hovers over it. This indicates that the button is clickable. In addition, all other names and labels are red, and only Rajasthan's label is green. This provides additional visual cues to push the player to press it and make them realize that upon pressing this button, they are being led to Rajasthan and that what comes next is a representation of the landscape of that place.

Level One

Upon pressing the Rajasthan button, the player is teleported into a sandy landscape that mirrors a rocky desert (see Figure 4). Although only one landscape was designed, the same landscape is played as three different levels, each with additional superpowers and goals. As described earlier, the player is required to explore the entirety of the playable area to collect all the ores and scrolls in a level. The player can run, sprint, jump, and crouch to reach various locations. However, in a decision that will be clarified later, the first level only allows a slower speed of navigation compared to later levels when powers are unlocked.

Figure 4. Rocky desert landscape that recreates the sandy dunes of Rajasthan. Screenshot from the game taken by the authors.

Periodic Table and Unlocking Elements

As described earlier, once the player has collected every scroll and ore in the current level, the game proceeds to the next screen and the player is greeted with a colourful rendition of the periodic table. The screen title informs the player that the collection of all the ores and scrolls from the previous level has now allowed them to unlock new elements from the periodic table. The table's design shows all the elements as greyed-out buttons, with only hydrogen (H) available from the beginning. Hovering over the H button changes its colour to indicate that it can be pressed.

Next to the periodic table itself, there is a dialogue box that says: "Every element will give special powers!" Another dialogue box informs the player that a period means the same number of electron shells, and that a group means the same number of valence electrons. Even though most element symbols are greyed out, they are coded by colours representing their element types. A key is provided on the left side of the screen, which relates each element to its periodic classification and type (alkalies metals, halogens, etc). For example, an element shown in green means that it belongs to the halogen family in the periodic table (see Figure 5). Other element types include alkali metals, alkaline-earth metals, transition metals, non-metals, noble gases, rare earth elements, lanthanoid elements, and actinoid elements.

Figure 5. Periodic table interface and unlockable colour-coded elements. Screenshot from the game taken by the authors.

This screen is intentionally designed to be abundant in information, as the player visits it every time they complete a level. The use of repetition in reinforcement learning is key (Jensen, 2005), and thus this screen is intended to allow players to learn about the periodic table through reinforcement and repeated visits. As soon as the players click on the H symbol for hydrogen, they progress deeper into the game.

Level Two

The next level is a recreation of the first playable level. One key difference is that the player is first greeted with an informational popup (see Figure 6), which congratulates them on unlocking the hydrogen element and details all the information about it, mentioning its atomic number, atomic weight, type, and major uses. It also informs the player that they have unlocked new navigational skills thanks to the elements they have recently unlocked. In the case of unlocking hydrogen as a power up, the player can now move and sprint much faster, adding to the fun and efficiency of exploration. Since hydrogen is used as a fuel in the real world, it was decided that jetpack fuel, which increases movement speed, would be a good power-up to represent this element. The goal of the game remains the same, which is to collect all the ores and scrolls; however, their numbers and locations have changed significantly. Therefore, even though the player has visited the landscape before, they must search for these items once again. As the players can now move faster with the help of their newly acquired power-up, the ores and scrolls are placed further apart to keep challenging the player.

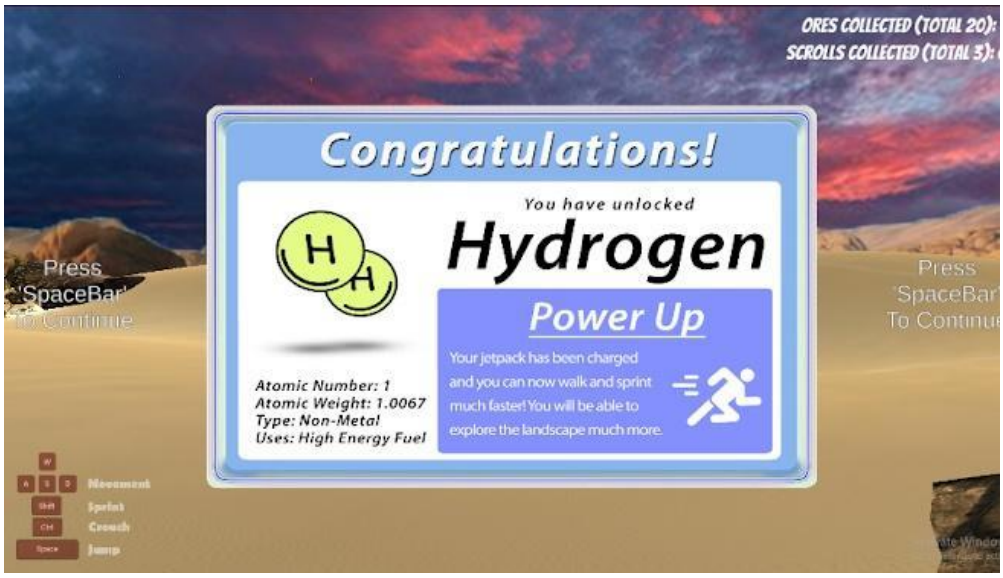

Figure 6. A power-up popup in the second level informs the player of their newly acquired capabilities. Screenshot from the game taken by the authors.

Certain locations throughout the game were designed to appear intriguing yet unreachable. For example, a traditional dome-shaped temple-like structure is placed atop a very high rock that the player can see in the first and second levels; however, the player is not granted the ability to reach the structure until the third level. The authors took this approach to push the player to be curious about certain places throughout the game, but to only allow them to access them after working hard. This also encourages players to look forward to the upcoming levels.

Another notable visual difference in the second level is that the sky, which was sunny in the first level, is replaced by an evening sky in the second. Similarly, music from the first level is replaced with a different Indian tune.

Once the player has finished collecting all the ores and scrolls from the second level, they are teleported back to the periodic table interface. The player can now see that helium is now accessible in addition to hydrogen. This is indicative of a gradual progress through the entire periodic table. The player can choose to unlock helium by clicking on it or return to play with the hydrogen power-up. When the player clicks on helium, they are transported back to the initial landscape for the final run.

Level Three

This time, as in the second level, a popup greets the player with all the details of helium as an element. Since helium is a very light element and is often used in the manufacture of floatation devices, it was decided that its power-up would let the player experience a higher degree of vertical

movement. The popup informs the player that they have gained the ability to jump much higher and land back down in a much lighter manner. The text also hints that the player can now reach places that were inaccessible in previous levels, such as high rocks and mountains. As with the second level, the sky has been once more changed from evening to a starry night, where the Milky Way galaxy is visible. The music has also changed to match the calm atmosphere. The player must revisit the landscape one last time and explore it to collect all scrolls and ores.

Game Conclusion and Restart

Once the player has achieved this feat, the game ends and a thank you screen greets the player, informing them that they have completed the demo version of the game. The player can exit the game or restart from the beginning.

Iterative Development and Evaluation

This section focuses on the stage-wise development of the game through iterative prototyping. Each of the following subsections describes a particular stage of development that was evaluated and rectified according to the needs and observations of participants and researchers.

Multi-Level Development

The initial development plan involved building three different landscapes for the player to choose from. As landscape design was intended to imitate the varied geography of India, three geographically distinct Indian states were chosen for development: Kerala, Himachal Pradesh, and Rajasthan, and CS started developing all three simultaneously. The landscape of Kerala was conceived as being coastal, with coconut trees and rich mineral veins of gold ore. Himachal Pradesh was designed to be surrounded by snow-capped mountains, abundant in deciduous forests, and intended to contain iron. Finally, Rajasthan was intended to represent dry, rocky desert rich in zinc and silver. All levels were designed to have distinct flora and terrains, unique visual aesthetics, and the different natural resources that the respective states contain.

Although creating various levels would have increased the range of playability and exploration for the player, it was becoming increasingly difficult to produce all three levels simultaneously with the same amount of detail and fidelity. For this reason, the levels set in Kerala and Himachal Pradesh were shelved for future development.

Iterations of Level Rajasthan

The following are the iterative stages through which the development of *Tattva Bhoomi* took place.

The first phase of development at this level involved sculpting the landscape to resemble dunes. Game assets that looked like rocks were built in Blender and were added to the landscape. Some ready-made game assets freely available on the Unity Asset Store were also imported into this level. The first iteration of the game only had a desert landscape, some rocks, and game mechanics that allowed the player to explore the environment. Metal ores were added in the next iteration as chunky silver rocks. There was no interface at this time, and the metal ores were not collectable.

The next iteration allowed the player to collect ores by walking over them, which emitted a thud sound as feedback. As this sound effect was not associated with metals or rocks, it was later changed to a metallic ping. This iteration also included a text box in the top right-hand corner that informed the player of the number of ores they had collected.

The third version of the game included a particle effect system that created the effect of wind blowing and sand particles being swept in one direction. This iteration also included a 3D cube that was coded to be picked up by the player by clicking it. Also in this iteration a pickup mechanic was tested where the player had to use the mouse and click on certain items to pick them up. However, the pick-up interaction with the object was later abandoned in favour of an approach-based. This version contained an object called an "information nugget," a pink sphere half-buried in sand that displayed text when the player approached it. The information nugget was designed to give out learnable information on approach; however, as it was not contributing to the game's progress, CS converted the information nuggets into collectable scrolls in later stages. This was done to motivate the player to collect all the information and to give them a sense of achievement. Lastly, this game version showed a map of India in the beginning, with a button that read "Rajasthan." The player could click on the button to reach the first playable level.

In the fourth iteration of the game, font of the text box was changed from Arial to Edu TAS using the TextMeshPro function in Unity to look more aesthetically fun and game-related. This version also included a 300 seconds timer before the level automatically ended. This was done to ensure that the player would be motivated to gather all collectables before the time ran out. When the timer ran out, the player was returned to the map screen. It was observed that the simulated harsh sunlight created very dark, almost black shadows in some parts of the landscape. As a result, some secondary lighting was added to brighten these areas so that they were easier to see and navigate through.

It was in the fifth iteration of the game that the sound of the ore collection changed from a thud to a metallic ping. In addition, the collection of information nuggets was made mandatory for the completion of the level. Another addition was that of a four-directional signboard indicating that the different directions would lead the player to the various cities of Rajasthan: Udaipur, Jaipur, Jaisalmer, and Jodhpur. The signboard was placed in such a way that the arrows of Udaipur pointed towards the playable landscape, signalling that the player was heading towards the areas in and around Udaipur. Another game mechanic to ensure that the player understood they were travelling to Udaipur was a popup note that read: "Now entering Udaipur." The note was designed to be triggered when the player walked slightly towards the playable area.

The next major development in the game was the addition of a periodic table interface, which allowed the player to unlock an element and progress further in the game. The initial colour scheme used in this interface conflicted with the game's general visual design and was later changed to match the scrolls and the overall aesthetic of the game. Upon clicking the "H" button on the interface, the player was transported to the second level and greeted them with a placard containing information about the unlocked element and the new power-up. The third level was introduced at this stage of development, where the helium power-up could also be unlocked. The power-ups representing hydrogen and helium were ideated and programmed in this version. At this point, the score text in the top-right corner carried over the score from the previous level. We observed that this was confusing for the player, who could not distinguish the new level from the previous one. Therefore, the score text was later programmed to reset on each level, and the score needed to complete each level was designed to be different (e.g., the player could have to collect three scrolls and ten ores in Level 1, and five scrolls and eight ores in Level 2).

The seventh iteration added a text box to the title screen, providing a brief description of the game and cementing the player's role as an adventurer in search of periodic elements. The map on the second screen was changed, and all of the states and union territories of India were added as unclickable buttons. The use of distinct symbols to represent the UT of India was also implemented at this stage of development, and informative collectable scrolls were introduced. Soft spotlights were added to the scrolls to make it easier for the player to spot them in the vast landscape. Looping Rajasthani background music was also added; however, at this stage, it was still the same for all playable levels.

In the eighth version of the game, the font for the names of the states and UT was changed to improve readability. A semi-transparent picture guide was added in the bottom left corner of the screen to indicate the key

bindings. This was done to guide the player in case they had forgotten about them or were new to computer gaming. Lastly, a stone archway was added to provide directional guidance to the player and the colour scheme change in the periodic table (as shown in Figure 5) was implemented. The skies of the second and third levels were also changed from sunny daytime to sunset evening and starry night, respectively, with the intention of giving these two levels their own identity.

Up to this point, the only metal available for collection throughout the game was silver, and its ore, galena, was scattered throughout the landscape. In the ninth iteration of the game, the ore sphalerite was also added for zinc metal. In addition, a mechanism was programmed to alert the player of the ore they had collected. This was done to educate the player about the names of the ores and the metal they provide. A generic ancient Indian architectural heritage structure was added atop one of the highest rocks, and a spotlight was added to encourage the player to try and reach it. These structures are known as "architectural weenies." A term coined by Walt Disney, weenies are high-rise structures in certain landscapes that allow an individual to triangulate their location in relation to the structure and add a sense of mystery (Sehell & Shochet, 2001). It was decided that although the structure would be visible on all levels, the spotlight would only appear on the third level. This was intended to hint that this inaccessible location was now reachable because of the player's latest power-up. Some collectables were shuffled and placed in more inaccessible locations than in the previous two levels. This was done to encourage player to explore the entire landscape and make the game slightly more challenging. The looping Indian music, as well as the score text, were also changed and differentiated for each level.

The final iteration of the game before the pilot test included the removal of the timer. This was done because many participants who tested the game during its development felt that the timer was changing the focus of the game. They felt that the presence of a timer made them more inclined to collect all the scrolls as quickly as possible, rather than taking the time to read each one thoroughly. As the scrolls were designed to be one of the main sources of information, the presence of a timer was considered detrimental to the purpose of the game. In the new version, the levels progress only when the player has collected all the collectables, as opposed to the level ending due to the timer. Removing the timer also allowed the players to explore the landscape at their own pace. Another major change at this stage was the design of an unravelled scroll. As the role of the scrolls was to provide scientific information, the original design was quite text intensive. Players found this relatively dull and unappealing, resulting in a lack of attention being paid to the information the scrolls provided. Another issue with the scrolls was that they unfolded vertically, leaving little

space to include information. These problems were solved by firstly making the scrolls unravel horizontally, which provided much more visual space. Second, the authors decided to make the information contained within the scroll more visual and pictorial rather than textually descriptive. For example, the scroll that described the "uses of silver" initially harboured a hundred-word text block, which was a considerable amount of text to fit into such a small space. The same scroll was redesigned to provide the same information using pictograms. This change in design was expected to be more advantageous as it allowed the use of a larger font size due to the lack of a large descriptive text box. Another advantage was that the information could be presented through images, which was more appealing to the player and in line with the cognitive theory of multimedia learning, which states that the creative use of images and words can maximize learning (Sorden, 2013). As a result, this design change was implemented in all scrolls.

Applying the Design Criteria

In this final section, the educational and multimedia design of *Tattva Bhoomi* is compared to the criteria proposed by Solanki and Mathew (2021). These criteria are used as a checklist to see whether the development of the game followed the protocol developed for this study, the protocol here being the criteria that were developed after intensive literature review and first hand research. The evaluation of the game itself was conducted later in a research project using pre-test and post-test interventions (see Solanki, 2023). This paper limits itself to describing the process through by which the development of the game tried to stay faithful to the criteria proposed by Solanki and Mathew (2021).

Effective Educational Design

Five criteria have been proposed for effective educational design: content appropriateness, player-reliant gameplay, problem transmission and solving, learning through exploration, and goals and reward systems (Solanki & Mathew, 2021).

Content Appropriateness

The research project intends to develop the game for multidisciplinary learning; therefore, the content of many subjects is presented in different ways. It was ensured that the subject content was aligned with the school's curriculum. Specifically, the chemistry content was taken from the chapter "Classification of Elements and Periodicity in Properties" of the Central Board of Secondary Education's 11th Standard Chemistry course curriculum (Periodic Classification, 2022). The subject matter is represented honestly; however, some game objects, such as metal ores, are not recreated with real-life accuracy, as it has been shown that players are more receptive to media engagement when game objects look more fun and abstract (Alfadhli

& Alsumait, 2015). The game contains information on snippets from various subjects, and because of that, the teaching time of the same subject matter in schools could not be determined and would not be an appropriate measure for comparison.

Player-Reliant Gameplay

According to Solanki and Mathew (2021), player-reliant gameplay occurs when the game progresses and develops with the speed and decision-making of the player. The story of *Tattva Bhoomi* is designed in such a way that it can only progress when the player has gathered all the collectables. The collection order is not predetermined and is dictated by the player, thus making the game progress only when the player wants it to. Ideas for further customizations were conceptualized, but since this game is a demo version of the full game, they were not implemented at this stage. In the future, the design intends to offer the player many elements and multiple simultaneous power-ups, with the player being able to choose which ones they would like to unlock. This would make the gameplay unique to each participant. At the moment, environmental manipulation is possible in a limited manner as the player can remove scrolls and metal ores from the ground and surrounding rocks. The responsibilities have been divided between the player and their in-game avatar, with the avatar knowing how to jump, sprint, and gather the collectables. However, it is the player who must determine the strategy and guide the avatar.

Problem-Solving and Transmission

The order of the problems in this game remains linear, but the complexity of the information provided to the player increases steadily. For example, the information scrolls of the first level provide only the basic uses and descriptions of the elements. By contrast, the scrolls of the third level inform the player of what d-orbitals are in chemistry and why the classification of elements is important to the field. Constructive frustration, described in literature on game-based learning as the feeling of struggling with a task yet being genuinely interested in seeing it through, was designed to be provided by a large landscape where the player gets tired of roaming around but is met with frequent rewards in the form of half-buried scrolls and metal ores. Repeated visits to the same level with different power-ups are intended to hone the player's skills and to increase their expertise in this mode of gameplay and environment. Information resources are designed to vary in all parts of the game: The title screen provides a brief description of the potential India's natural resources in, the gameplay allows the player to access the various kinds of information within the scrolls, and the repetitive collection of the metal reinforces the learning and remembering of names of their respective ores. The periodic table interface teaches the player about the different types of classified elements, and the

popup placards on the second and third levels inform the player of the different descriptions of the element they have just unlocked.

Learning Through Exploration

The game harbours exploration possibilities through its vast landscape. The exploration experience is further enhanced in the later levels of the game (Level 2 and 3), where the player can run faster and jump much higher, allowing them to climb to higher places. Situational learning is encouraged by establishing the player as an explorer responsible for gathering elements and scrolls. It is also reinforced by the first-person perspective, which may allow the player to better relate to the avatar and feel a greater sense of embodiment, as some studies have suggested (Denisova & Cairns, 2015; Gorisse et al., 2017). The environment, as mentioned earlier, has many interactive components: scrolls, metal ores, a periodic table interface, and a map selection interface being a few of them. At this stage, the game did not employ any sandbox features where the player could manipulate and experience the game entirely as they wish; however, permanently removing the time allowed the player to take as much time as they wished and tinker with the environment and objects.

Goals and Rewards Systems

The game is designed to motivate the player by always providing them with something to look forward to. Every screen or interface motivates the player to think about what might come next. For example, the title screen beckons the player to start their journey and find the marvels within, the map screen urges them to select Rajasthan and witness what lies ahead, and the scrolls keep reminding the player that the next level will be unlocked once they have gathered all the collectables. The periodic table informs them that the elements they unlock will provide them with power-ups in the next level, and the popup placards inform them of their newfound abilities and their potential uses. The rewards the player receives after completing the level allow them to explore the next level more efficiently, and these rewards increase as the player progresses through the levels. For example, the second level can be explored more quickly by unlocking hydrogen (as hydrogen is described as jet fuel), while the third level can be explored faster with better jumps because of helium, a lighter element. This makes the reward system tangible and proportional to the amount of work the player is willing to put into exploration. The rewards contribute to the game progression, as they are the structural mechanics that allow the player to access some locations that were previously inaccessible. To remind the player that they have achieved certain milestones, audio and visual changes were incorporated into the game levels. For example, in the second level, when the player has unlocked hydrogen, they hear a new piece of looping music and witness an entirely

new sky. These placeholders for milestones change in the third level as well.

Effective Multimedia Design

To assess the effectiveness of multimedia design, four criteria are discussed: technology selection, task analysis, content representation, and interactivity. These four criteria may not constitute an exhaustive list, but the original paper can be accessed to assess how a wide set of criteria were selected and then distilled into these four categories (see Solanki & Mathew, 2021).

Technology Selection

As the educational objective of this research was to impart multidisciplinary learning through educational games, it was important to incorporate elements from many school subjects. *Tattva Bhoomi* has snippets of information from geography, chemistry, and civics. It employs the basic practice of trajectories and how high jumps function, bringing in some aspects of physics. The score text lets the player constantly count how many collectables remain throughout the game, whereas the design of game objects and music contribute to the discipline of art. The range of player abilities required to play this game is limited to the operation of a mouse and keyboard. This is intended to allow most students to work with the system they are already comfortable with. A more inclusive system that allows players with different disabilities, such as visual, hearing, or motor impairments, could be developed in the future. The game appears robust in its optimisation for usability and playability, having been tested on three different machines with very low to moderately high specifications. The game runs smoothly on all these machines and is thus approved for testing. The needs and preferences of learners from various demographics can be evaluated and accommodated in future iterations of this game.

Task Analysis

The tasks are designed to be easily solved to accommodate participants who are not familiar with video games. Approach-based game mechanics were adopted, with an interaction being triggered when the player approaches the respective object in-game. Although game interaction remains approach-based and at a constant difficulty level, the navigation and distribution of resources are designed to progressively increase in difficulty. All tasks are designed to be achievable using a mouse and keyboard.

Content Representation

As the educational content comprises facts from many subjects, it was decided to take a semi-realistic approach to designing the game's setting. The landscape design follows a realistic representation, so that the player

understands what a rocky desert looks like, with its dunes and dust winds. The scrolls and metal ores are designed to be exaggerated versions of actual scrolls and ores, so that they stand out from the landscape and attract the player's attention. As mentioned before, the original design of the scrolls initially presented information through text; however, this was changed in later iterations to pictograms. When the player is informed that they are in a mine in Rajasthan, for example, the scrolls show the name of the mine as well as the city in which it is located on the accompanying map of India (see Figure 1). This serves the purpose of conveying information through multiple modes of representation. Interaction and information dispersal have been designed to be made available through visual popups, audio cues, and on-screen text. The order of the coursework-based information (concepts from chemistry) that the students learn through this game is structured to be simple in the beginning and more complex as the player progresses in the game.

Interactivity

The game's design is intended to instigate interest in the player by providing incremental interaction opportunities. These opportunities include collecting ores and scrolls, unlocking certain elements, picking out Rajasthan as the playing level, and varying the intensity of running and jumping. Instructions given in the game are clear to the player and train them to play without any personal guidance. A list of key bindings is provided as a semi-transparent overlay during gameplay, so that the player does not forget them. Clear instructions on how to progress in the game are given on multiple interfaces (e.g., the ores/scrolls that need to be collected are shown both in the score keeping on the top left and in the introductory scroll) and choice-making is marginally narrowed down so that the player does not get overwhelmed by options. Feedback is provided through text boxes, visual images, environmental settings, music changes, sound effects, and encouraging dialogues.

Conclusion

The above discussion demonstrates that *Tattva Bhoomi* meets most of Solanki and Mathew's (2021) criteria for designing an effective educational game. Issues for further work include the universalisation of accessibility, increased customisation, and expansion of game levels.

Tattva Bhoomi has been developed to teach middle school students (equivalent to 10–16 years of age in India) the concepts of classification of chemical elements and the periodic table. The pilot study conducted with 38 participants of the 8th standard showed that 37 students performed better in the post-test after the game-based intervention had been applied (Solanki & Mathew, 2022). Another larger study has been conducted in three schools and assessed the pre-test post-test change among an

experimental group and a control group of 71 participants respectively (see Solanki, 2023) and reveals that the impact of *Tattva Bhoomi* is largely positive when it comes to short-term knowledge retention. However, it is mostly limited to the teaching of chemistry and has yet to be tested for long-term knowledge retention and for other subjects.

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