Innovations

An exploratory study using the first-person role-playing game 'Tattva Bhoomi' to improve learning in middle school children:A quasi-experimental study

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Abstract
The advent of new technologies has revealed their pervasive nature, which has created a need for interactive content that utilizes the potential well. Digital games for education are such content that can be defined as learning applications that apply themselves to impart not just knowledge, but entertainment as well. The effective development of educational games is of utmost importance as the gaming and education industry hold in themselves vast swathes of untapped opportunities. Especially in India, where both the domains are now growing significantly. The gaming industry has been projected to grow to 169 billion INR in 2025 (1), while edtech (educational technology) is estimated to reach 780 billion INR by 2025 (2). This reveals the need for tools that can utilize the combined potential of edtech with gaming in India. The following research describes the development and testing of the game-based learning application Tattva Bhoomi that ties in with the above discussion about the edtech sector and the gaming industry. Chemistry is a subject with nuance and unique characteristics, which can potentially be improved with a technology-oriented approach that supports conventional learning in class. Tattva Bhoomi is a game-based learning application (GBL) developed to teach students about concepts primarily from chemistry but also provides secondary information from other subjects such as geography and social science. The paper is composed of two parts where the first section describes the iterative development of the game within the context of the design criteria generated by Solanki and Mathew (2021) for effective educational and multimedia development of games (3). The second section describes the use of a single group pre-test post-test quasi-experimental design to report on the effectiveness of this GBL on 38 school students between the ages of 11 and 17. The data on understanding elemental concepts of chemistry were collected using a 14-item questionnaire and the analysis was performed through a paired sample t-test method. The results gained through the analysis shed light on the effectiveness of using educational games-based applications as support structures within the modern classroom to enhance learning.

Keywords:* 1.Digital learning; 2.Design for education; 3.Digital games; 4.Gaming industry; 5.Game-based Learning; 6.Future of Learning;7. Indian education; 8.Classroom Intervention; 9.Learning Automation*

1. Introduction

Games have been shown to be useful in improving teaching and learning in schools (4, 5, 6, 7, 8, 9). On the other hand, Bennerstedt (2013) notes the problem of knowledge transference from the medium of gaming; however, they have also observed that these problems can arise in any unfamiliar activity that a participant might want to specialize in (10).

There have been several studies that have tried to administer games to impart learning of specific subjects and gauge the responses based on various demographics like age, gender, etc. (11). However, there seems a significant lacuna in literature when it comes to the impact potential that game-based applications can have in the Indian classroom (12, 13, 14). The studies have been useful in understanding the role that games can play in learning, however, research that can reaffirm these findings would help solidify the literature. There is also a need to contextualise the impact of games and learning on the Indian population, therefore, this study tries to bridge the gap between the general literatures and tries to map it with the findings in the Indian classroom.

This research comprises of two parts, the first contains a brief walkthrough of the game *Tattva Bhoomi* which was developed by the researcher. This section also contextualizes the development of the game with the educational and multimedia criteria generated by Solanki and Mathew (3) (See Table 1 and 2). The second part of the research implements *Tattva Bhoomi* in an Indian classroom with 38 students and reports on the findings of a pretest, intervention, and posttest.

2. Game Walkthrough

The game begins with a title screen that initiates and situates the player as an explorer visiting the land of India to collect resources. The intention is to let the player choose from the 36 states of India (28 states and 8 union territories). As this game is in its initial stages, only Rajasthan was unlocked for exploration. Once the user has chosen Rajasthan, they are redirected to a desert landscape where they can roam around and explore from a first-person perspective. The first scroll (collectable item) of the game informs the player that they are currently at the Zawar mines of Rajasthan which are rich in certain ores, namely copper, silver, and zinc. It informs that the complete collection of all the metal ores, as well as all the scrolls, would let the player progress to the next level.

The user then has to roam the landscapes searching for ores and scrolls to collect. Each ore collection is reinforced with an audio ping along with a text popup of the ore names. The score text on the screen also records this collection. The process is similar for scrolls as well with one key difference being that every time a player collects a scroll, it unravels to reveal bits of information about the elements and ores in the initial levels and then the process and need for classification of elements in the later levels. The information dispersal has been designed to be incrementally complex.

When the user has collected all the scrolls and ores from their current level, they are redirected to a new screen which shows the periodic table with all the elements greyed out except one, hydrogen. The screen congratulates the player for completing the level and informs them that their hard work has let them unlock a new element which will consequently provide them with power up. Upon clicking hydrogen, the player is redirected to the second level where a visual pop up informs them that the unlocking of hydrogen has given them the ability to traverse the landscape faster and more efficiently. It also informs the player of the general uses of the element and some of its atomic properties. The player has to once again collect everything, after the completion of which they are once again redirected to the periodic table screen. This time they unlock helium, which being a lighter element provides them with a higher jump to reach higher places which were inaccessible initially. The completion of this level marks the end of this game version and congratulates the player on the achievement. In total, there are 60 ores (split between galena for silver and sphalerite for zinc) and 12 scrolls spread within three levels.

3. Methodology

A prerequisite to testing the intervention was to build Tattva Bhoomi in accordance to the design criteria developed by Solanki and Mathew [3]. Table 1 and 2 showcase the educational and multimedia criteria, their elements, and the fulfillment of each element by Tattva Bhoomi, respectively.

In order to comprehend the potential of effect on learning through this game, a single-group pretest-posttest was conducted which was later analyzed using the paired sample t-test method. The testing conditions were ensured to be identical, where a 14-item questionnaire was employed that the participants had to complete before and after the intervention. The results of both were then compared to see if any changes existed and if correlations could be drawn from this research. Ethical considerations were taken into account through the approval of the ethical committee at IIT Hyderabad. Along with that, a consent form was provided to the parents/guardians of the participants who described the study in its entirety and informed them of their rights to withdraw from the study whenever they wanted.

4. Sample and Data

An offline questionnaire was used for data collection. The participant sample was the entire student body of the 8th, 9th, and 10th standard of the DAV school which is within the Indian Institute of Technology, Hyderabad. 43 participants were recruited for the study, out of which 5 participants were not available for the post-test leaving 38 participants that went through the pretest, intervention and post-test. Response analysis showed that out of the 38 participants, 20 were boys and 18 were girls. All the participants were aged between 11-16 years with the average age being 13.09.

TABLE 1: Criteria for the effective educational design of game-based learning applications by Solanki and Mathew [3], and its fulfillment by Tattva Bhoomi

Effective Educational Criteria		
Criteria	**Elements**	**Element fulfillment in Tattva Bhoomi**
Content appropriateness	Is in line with the curriculum and evaluation	Chemistry content was specifically from the 'Classification of Elements and Periodicity in Properties' chapter from the course curriculum of the 11th standard of CBSE India
	Reflects subject matter honestly	Honest representation of subject matter was created to be visually fun
	Matches conventional teaching time of subject matter	Teaching time of the in-game subject could not be determined as the game contains snippets of information from a range of subjects
Player reliant gameplay	Story progression through user action	Story designed to progress only when the player had gathered all the collectables
	Customization and personalization	Ideas for more customization and personalization have been formulated but as this game is a demo version of the full game, they were not implemented at this stage.
	Environment manipulation and player empowerment	Environment manipulation is possible in a limited manner by the player as they can remove scrolls and metal ores from the ground and surrounding rocks.
	Bifurcated responsibilities between the player and the in-game avatar	The in-game avatar knows how to jump, sprint and gather the collectables, but it is the player who has to determine the strategy and guide the avatar.
Problem transmission and solving	Order of the problems	Linear order of problems
	Increasing complexity	Steady increase in complexity of information
	Solved work examples	Provided in class
	Constructive frustration	Large landscape and obscure location of ores and scrolls
	Contributes to increasing expertise	Repetitive exploration intended for reinforcement learning
	Varied resources of information	Information gathered from all levels and all interactions
Learning through exploration	Exploration possibilities	Navigation abilities are increased every level contributing to greater exploration capabilities
	Encourages situated learning	The player is established as an explorer and resource collector in the title screen
	Interactive environment	Scrolls, metal ores, periodic table interface, map selection
	Sandbox features	No sandbox features at this stage
Goals and reward systems	Generates Motivation	Most elements are designed to motivate the player to move forward

	Rewards are proportionate to the difficulty	Rewards and their collection difficulty are proportionate to the level that the player has reached
	Tangible rewards	The rewards are reaped in the form of upgraded navigational superpowers
	Rewards contribute to story progression	The rewards help move the story further
	Placeholder for milestones	Music, sky-scape, superpowers, and accessible locations change with each milestone achieved

TABLE 2: Criteria for the effective multimedia design of game-based learning applications by Solanki and Mathew [3], and its fulfillment by Tattva Bhoomi

Effective Educational Criteria		
Criteria	**Elements**	**Element fulfillment in Tattva Bhoomi**
Technology Selection	Complements the educational objective	Chemistry factoids are taken from conventional class syllabus chapter
	Complements the range of user abilities	User ability required is only mouse and keyboard operation
	Robustness of equipment and apparatus used	Tested on multiple devices of varying specifications before deployment
	Flexibility towards the needs and the preferences of the learner	More inclusive system that can allow users with different abilities needed in future
Task Analysis	Solved example and progressive complication	Approach based game mechanic for resource collection, but incremental difficulty in finding said resources
	Achievable tasks through the multimedia operation	All tasks are designed to be achievable through the combined use of a mouse and keyboard.
Content Representation	An appropriate representation of educational information	Semi-realistic approach for designing the game setting and factoid representation
	Multiple inputs i.e. visual, audio, verbal, on-screen text	All included
	Structured order of information representation	Incremental order for information for each level
Interactivity	Supports emergence of interest	Interest instigation in the player by providing incremental interaction opportunities
	Offers a range of interactions	Scrolls, metal ores, periodic table interface, map selection
	Guided instructions	List of key bindings provided as a semi-transparent overlay during game-play
	Meaningful Feedback	Audio pings, visual popups and kinetic jerks act as input feedback

5. Questionnaire

The offline questionnaire was devised in English and contained questions from the chapter 'Classification of Elements and Periodicity in Properties' from the course curriculum of the 11th standard of CBSE India. The material was taken from the 11th standard to ensure that the students had minimum or no knowledge of the material intended to be taught. This was also verbally confirmed in the classroom by the researcher by asking the students whether they were familiar with this topic. Out of the 14 items, 9 were multiple-choice questions with a single answer, 2 questions required descriptive answers, 2 questions needed the participant to shade an empty periodic table, and 1 question required a numerical answer. The grading was done as follows: a correct answer was given 1 mark, a partially correct answer (for descriptive answers) was given half a mark, and a wrong answer was given no marks. The questionnaire formation was made using Hinkin's (1998) tutorial and Peterson's (2000) BRUSO model [15, 16].

6. Delimitations

Although the research does not employ convenience sampling, and the selection of the entire classes contribute to adequate randomization, it still remains a sample from a single school. A future study spanning multiple schools from varying backgrounds would help in justifying the significance of the findings. An additional multimedia apparatus that allows for specially-abled students to also participate would be more inclusive. As this study concerns itself with games, education, and learning in India, a translation of the game into local languages would also shed light on the impact of vernacular changes on learning.

7. Analysis

In order to understand the results, a paired sample t-test was used to analyze the influence of the game-based learning application Tattva Bhoomi on the students. Response analysis showed that out of 38 students, 37 students had an increase in overall performance in the post test, with the mean average of the pretest and posttest being 3.98 and 9.14 respectively. The two-tailed P-value was shown to be less than 0.0001. By conventional criteria, this difference would be considered to be significant.

Based on the above-mentioned results, the intervention is found to be a significant determinant of improvement in the learning of participants. This is adequate evidence to support the idea that the use of appropriately designed educational games, in this case, Tattva Bhoomi, can be employed to support teaching-learning in the middle school classrooms in India.

8. Conclusion and Discussion

This paper presented the development of a game-based application Tattva Bhoomi in the context of effective educational and multimedia design criteria. It outlined a walkthrough of the game and presented the in-game elements that fulfill the aforementioned criteria. The research then moved on to implement this application in the middle school students of DAV school, Hyderabad. The experiment included a pretest in the form of a 14-item questionnaire, an intervention in which the participants played the game for three consecutive days for one class period each, and finally a posttest reapplying the same questionnaire as before. It needs to be noted that the game intervention was used as a support tool in the classroom, and in no way do the findings indicate educational games to be a replacement for conventional methods yet. The findings are also taken from a post-test that took place a day after the intervention, therefore, we cannot comment on the long term information retention from this study.

The results of both the tests from 38 participants were analyzed using a paired sample t-test. The analysis calculated the two-tailed P-value to be less than 0.0001, which can be considered significant at this stage. Out of 38 participants, 37 showed an improvement in their overall scores. The results of our experiment support the idea that there is a relationship between the utilization of educational games in the classroom and increased learning in middle-school students (ages 11-16). This is a significant finding that indicates that well-designed educational games could be a part of the chemistry (and consequently STEM subjects) curricula for this age group in India. A larger, future study that employs a significant sample from different parts of the country can help cement these findings; however, that is the scope of future research.

Fig. 1. Composite image of level 2 and level 3 with different skies in the game Tattva Bhoomi

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