An Interactive Elementary Tutoring System for Oral Health Education Using an Augmented Approach

Mitali Sinha and Suman Deb(✉)

Department of Computer Science and Engineering,
National Institute of Technology, Agartala, India
mitalisinha93@gmail.com, sumandebcs@gmail.com

Abstract. The conventional elementary education system in India is mostly guided by formal content development, focusing on areas like math, language, science and social-science. Children tend to retain very little knowledge about other important areas of learning like heath care, which needs to be developed in their foundation years. The education on oral health is one such example which is not given the focus they ought to be. Considering its importance in early education, we propose a learning environment where children would gain knowledge through constant interaction with an intelligent tutoring system. The system addresses the challenges in developing a learning environment for children by introducing audio-visual effects, 3D animations and customizing the tutoring process to provide user-controlled pace of learning. It also employs the Wii Remote for imparting a tangible hardware interaction with the interface. This paper describes the proposed system and the studies conducted on treatment and control groups to evaluate its efficacy and compare the learning outcome at various domains. Experimental results depict positive effects on learning in the proposed technology-enhanced environment and paves a way for the deployment of more interactive, technology-driven learning process in the elementary education system.

Keywords: Intelligent tutoring system · Wii remote · Tangible interaction

1 Introduction

Intelligent systems are rapidly becoming a part of the modern education environment which leads to what is known as technology enhanced learning (TEL). Although TEL is often related to e-learning, we can also refer to it as a hardware or ICT (Information and Communication Technology) based teaching environment. The teaching and learning process is highly benefited with the advent of technologies like computers. Turning computers into an intelligent tutoring system (ITS) and designing careful instructional strategies helps in building a learner-centric process. Our work presents the design and evaluation of an oral health based ITS for young children. The children must be educated at a very early stage and realize the importance of learning about oral

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health and hygiene. With a goal of designing a learner-centric process, an intelligent tutoring system is proposed which keeps track of a learner's progress and guide him or her by generating feedbacks throughout the process. Our idea is to introduce a gaming element in the tutoring system along with learning contents, as research indicates that children show a high degree of interest and engagement in a playful learning environment [1]. There is some evidence that favors the understanding of abstract concepts more easily with physical artifacts and tangible user interfaces [2, 3]. The Nintendo Wii remote is introduced as a tangible tool to enhance the interaction with the system. The interface allows 3-dimensional interactions with the user delivering knowledge at both visual and auditory channel. By effective use of animations and audio-visual effects throughout the play, the system aims to successfully deliver educational contents to the learners.

Our research work also compares the learning outcomes between the traditional learning environment and the technology-enhanced learning environment in the cognitive domain. We have also assessed the outcomes in the affective domain and investigated the development of psychomotor skills among the children.

2 Background and Related Work

An intelligent tutoring system possesses important features like personalization, interaction, and engagement in learning. In a traditional learning environment, the teaching and learning system often becomes a one-way process where the teacher acts as a controller of the pace of learning. In a large classroom environment, it becomes difficult for an instructor to keep track of the progress of each student individually. Research works suggested that learning outcome increases with the introduction of private tutors in the process [4]. Private tutors are able to monitor the learning curve of individuals and suggest remedies whenever required. Thus, in the absence of private tutors, ITS can be used for tutoring different concepts. Unlike the traditional process, an ITS is designed carefully to deliver knowledge in a learner-controlled pace. It strives to understand the level of tutoring to be provided to the individual learners and delivers educational contents accordingly. There are also many examples where intelligent tutoring systems are employed and found to be effective [5–9].There is some evidence that shows an increasing interest and motivation in learning with the appropriate use of technology at early childhood stages [10, 11]. The research works of Montessori also provided hints of young children grasping complex knowledge very easily in a playful environment with the help of physical artifacts [1]. Thus, in quest of providing an augmented tangible interaction to the users, the Nintendo Wii remote is employed in the system as a tangible tool.

The system also introduces a notion of game-based learning where children learn different skills and knowledge through a game. The significance and effects of digital games in educational domains are studied extensively. A multiuser learning game called Quest Atlantis resulted in learning gains for various topics and adopted in multiple school environment [12]. Also, a game-based approach to teaching nutritional course depicted good results on learning [13]. As an experimental example, the oral health based tutoring system is proposed in our work which aims at imparting knowledge about dental hygiene. A limited number of research work has been carried out in the field of dental health education being addressed by an intelligent tutoring system. The study of Ho et al. [14] employs a Wii remote to investigate its effect as a TUI (Tangible User Interface). Their study showed improvement in memorability and fun factor in learning but does not provide better results in cognitive development among the users. Gerling et al. proposed a serious interface design for dental health based on the Wii remote interaction by introducing additional gaming elements [15]. Another serious game was designed by Chang et al. which focused mostly on developing the psychomotor skills and did not keep an account of the interest and motivational factors which may result in dissatisfaction in the future [16]. Although, the above studies were successful in including gaming instincts, by carefully adapting user-centric designs and including better methodologies can definitely result in better learning outcomes.

The proposed system attempts to provide a balanced learning system which includes both educational contents and fun factor. To make the learning interesting our system is developed in a 3-dimensional environment with the use of proper animations and visual effects. Finally, a detailed study of outcomes in cognitive, affective and psychomotor domain helps in strengthening the idea of employing an intelligent tutoring system in learning educational contents.

3 System Architecture

The system provides an enhanced learning environment to the users with the help of animations, hardware interactions and a tutoring process running in the backend. It aims for a proper blending of factual knowledge and its application. Animations and picture clips along with audio effects render the factual knowledge about dental health and hygiene. Users are asked to perform different tasks or solve a problem depending upon the factual knowledge gained at different levels (As an instance, the user is asked to match the name of a tooth to the 3D model of the tooth displayed on screen). As the user works through the task, the system keeps track of his or her actions and help in progressing towards the solution through feedbacks.

The system is divided into different modules on the basis of their functionality as shown in Fig. 1. It comprises of a user interface through which the users interact with the system, a profile base that keeps the profile information and history of interactions for individual users, a hardware interaction module which facilitates the hardware interactions with the system, a knowledge evaluator that evaluates the knowledge of the user with the help of the task formation module and knowledge repository, a tutoring module which tutors the user throughout the task with necessary feedbacks with the aid of a feedback module.

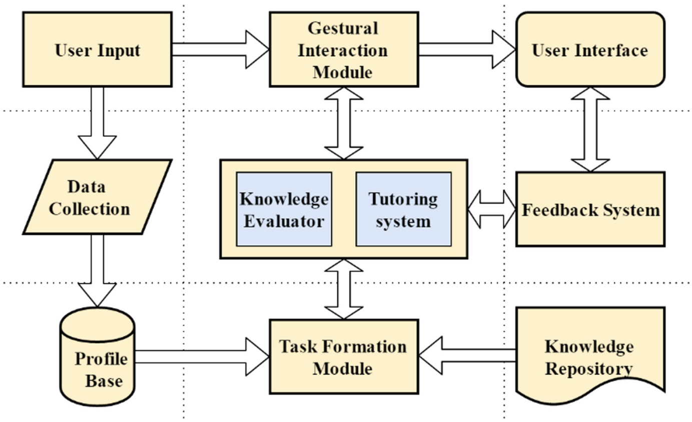

Fig. 1. System interconnection modules

3.1 User Interface and Gestural Interaction Module

The user interface facilitates interaction with the system. It is developed in a 3D designing environment using tools like Unity3D and Blender for experiencing an enhanced interaction and better understanding of the concepts. The system employs the Nintendo Wii remote for a tangible interaction. The Wii remote is a remote controller for a Japanese gaming console called Wii. Its motion sensing capability differentiate it from other traditional remotes. It has the ability to digitally manipulate items allowing gesture recognition and pointing of objects on a screen. The gesture recognition is guided by the three-axes accelerometer and its infrared sensing capability determines the location on the screen where the remote is pointing. The Wii remote connects with a computer via Bluetooth connection and thus provides a simple and wireless communication medium. It is employed as a tangible device in the system where it imitates the movement of a 3- dimensional brush model on the screen thus providing an augmented interaction with the system. The application includes a section where the user performs a gameplay with the Wii remote and learn few psychomotor skills.

3.2 Profile Base Module

The Profile base module is responsible for keeping the details of every user along with their performance history. The system is designed to impart knowledge to different groups of users with varying capacity and methods of learning and accepting information. This division is based on the Piaget's theory of cognitive development [17] where he proposed four stages of cognitive development as shown in Fig. 2. According to Piaget, at the sensorimotor stage the children understands through senses and actions, at the preoperational stage they understand through language and mental images, at the concrete operational stage, they tend to gain knowledge through logical thinking and finally through hypothetical thinking and scientific reasoning at the formal operational stage. The proposed system focused on parts of the preoperational and concrete operational stages forming two levels namely POP (5–7 years) and COP

(8–10 years). The user starts experiencing the system by first interacting with the user profile based module and entering their details (where the primary factor is the age group). The User_Name field helps the system to interact with the user with his/her name throughout the gameplay giving a sense of empowerment and making them in-charge of their actions. The Age field is used by the system to direct the user to either POP or COP level where depending upon the level, information is provided to the users. Thus, data collected by the profile base module guide the tutoring system to continue the process of further evaluation.

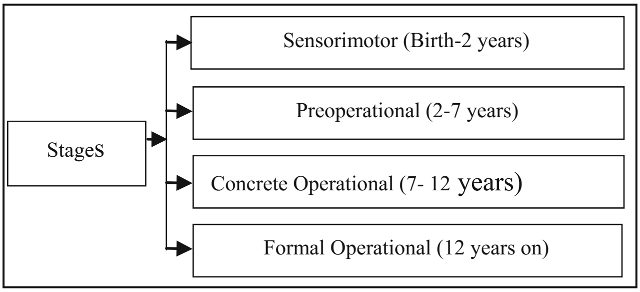

Fig. 2. Piaget's stages of cognitive development

3.3 Knowledge Repository and Task Formation Module

The knowledge repository is a metadata store that holds information regarding each concept, the problems generated and their solutions. Whenever a solution to a problem is submitted by the user, it is processed by the knowledge evaluator with the help of the knowledge repository. The task formation module is responsible for creating tasks for the user at different levels.

3.4 Feedback Module

The feedback module is responsible for guiding the users through stimulant learning and task solving. Three types of feedback mechanisms are designed as follows: audiovisual feedback serving as problem hints, movement-based feedback, and report-based feedback.

Audio-visual Feedback. As the user initiates a task, the feedback module generates audio-visual feedbacks whenever the user finds difficulty in solving a problem. The feedbacks are generated in the form of text, video clips or animations on the screen. To build up the interest of the user during the gameplay, they are also greeted for successful completion of the task. Figure 3 shows a snapshot of scenarios before and after the play. After successful completion of a level, the system appreciates the user's effort by displaying smileys and congratulating them. This kind of interactions helps in accelerating user engagement by addressing them emotionally and boosting their confidence.

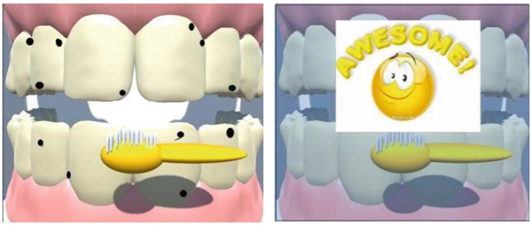

Fig. 3. Scenario before and after the successful completion of task (left to right)

Movement Based Feedback. Feedback is also generated to help the user for making correct movements with the Wii remote. A pre-determined threshold value for the accelerometer data of the Wii remote is set. If the accelerometer data acquired at any instant during the play crosses the threshold value, a feedback is generated. For example, if the user is moving the Wii remote too fast crossing the limit, then the user is prompt on screen to slow down the pace. Again if the user is showing no movement for a preset amount of time, he or she is asked to either quit or continue the play as a result, the movement based feedback helps in developing psychomotor skills by limiting the movement of the Wii remote.

Report Based Feedback. At the completion of each level, a performance report is presented to the user giving a brief description of the outcome of the play. This report generation at the end of each level provides a basis for determining the level of difficulty to be adapted in next stage of the play and also helps in monitoring the psychomotor development in children.

3.5 Tutoring System

The users are tutored throughout the process by the tutoring system with the help of the information gathered from the profile base module, knowledge evaluator, and feedback modules. The tutoring system is guided by some predefined rules depending on which it determines the level of knowledge provided to the particular user. It then interacts with the user through the feedback module. On the basis of the information from the knowledge evaluator, the tutoring system decides the level of factual knowledge delivered. It processes knowledge at two levels (POP or COP) depending on the pretest results. Figure 4 gives the illustration of a generic scenario of problem-solving by the tutor system. As a problem is given to the user, the tutoring system helps him or her through the process by providing hints or explanations regarding the problem. The users are tutored with textual, video or animations by the feedback module. A problem is then presented to the user based on the concept discussed to decide whether to further tutor the user or move on and take next actions.

Figure 5 represent a more specific scenario in case a user fails to give a valid answer. A problem is displayed on the screen and the user is asked to choose the correct answer. Since the user failed to give the correct answer, the tutoring system displays a hint on screen. A molar tooth model is displayed along with an audio instruction playing in the background.

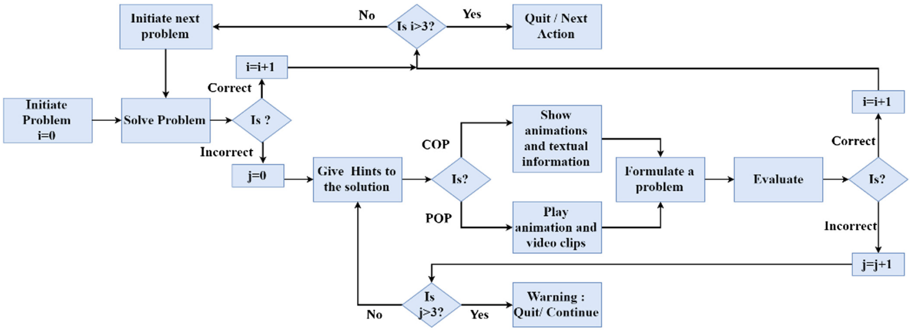

Fig. 4. Automatic feedback generation process by tutor module

Fig. 5. Problem displayed on screen; hint generated by tutoring system

4 The Application Development

The application is developed with a goal of blending learning content and gameplay effectively. In quest of finding ways to provide a tangible learning experience, the Nintendo Wii remote was selected. Therefore, the user gets a multi-model interactive environment where the sense of sight and hearing is exploited by the user interface and the sense of touch is provided by the Wii remote.

4.1 The Interface Design

The interface design constraints are guided by the principles of Mayer's cognitive theory of multimedia learning [18]. Mayer proposed five principles for effective multimedia design for the better understanding of educational contents as follows:

- **Off-loading.** Moving some essential information from visual channel to the auditory channel would help in the better transfer of knowledge.
- **Segmenting and pre-training.** Better outcomes are observed when lessons are presented in learner-controlled segments allowing time between successive segments. Also providing pre-training like knowing the names and behaviors of the system would facilitate the learning process.
- **Weeding and Signaling.** Excluding extraneous materials and including signals results in better understanding of a specific concept.

- **Aligning and eliminating redundancy.** Aligning refers to placing the graphics and related information at close proximity for better correlation. Also, avoid presenting redundant information visually and in spoken words.
- **Synchronizing and individualizing.** Transfer of knowledge is facilitated if narration and corresponding animation are presented simultaneously. Also, it is important to make sure that the learners possess skill at holding mental representations.

The first and third principles of Mayer's cognitive theory of multimedia learning is followed by using both audio and visual contents representing only the important materials. The system is designed to represent knowledge at different levels depending upon the ability of the user to grasp the concepts. Thus the second principle is justified by allowing a user-controlled pace of learning. The design is thoroughly revised for any redundant information being delivered and also placing graphics and related information in close proximity thus adhering to the fourth principle. Finally, Mayer's fifth principle is followed by narrating information and playing related animations simultaneously. The interface is designed using 3-dimensional designing tools to provide a better user experience since they primarily interact with the system through the interface. The Blender 3D modeling tool is used to create the teeth models and other objects for the game world. The models are then imported into the unity game engine as shown in Fig. 6, where the scripting is carried out in C# language.

Fig. 6. Teeth model in blender; teeth and brush model imported in Unity 3D game engine.

4.2 The Game Concept

The game supports two stages of learning as mentioned earlier i.e. the POP and COP stage. The POP stage is designed for the children belonging to the age group of 5-7 years while the COP stage is for the age group of 8-10 years. Although the underlying idea of the game is same for both the stages, the knowledge representation is slightly different. In the POP stage, the factual knowledge is represented to the user mostly through storytelling, animations, and auditory means. While in the COP stage, concepts are represented more broadly using textual, audio and video contents. The pre-knowledge test helps the system decide to either provide the user with the POP or COP stage. This is important because if the user starts with the COP stage and he or she is unaware of the basic concepts and terminologies explained in the POP stage, it may result in a gap in the learning process. Again if the user is given with the POP stage and finds the facts repetitive, he or she may lose interest in learning.

The idea of the game is to first provide factual knowledge to the users and then evaluate them by proposing simple tasks. As an instance, in the POP stage at first, the user is tutored and introduced to the shapes and names of the teeth by animating each tooth model on the screen along with audio effects. After each such sessions, the users are asked to answer some questions or solve a problem related to the concepts explained which are then evaluated by the knowledge evaluator. If the submitted answer is incorrect, the system provides some hints dynamically or suggests the user revise the concepts by going back to the animations as depicted in the Fig. 3.

The interface also includes three buttons which help to switch between three sections namely “Facts”, “Stories”, and “Play”. The “Stories” section includes small concepts related to dental health in the form of stories since storytelling tends to have a positive impact on learning among small children [19]. The “Play” section helps in developing psychomotor skills of children by helping them to learn proper brushing techniques.

The Nintendo Wii remote is employed in the environment as a tangible tool to imitate the brush model on screen. The user needs to hold the Wii remote and gently clean away the black dots making small circular movements as shown in the Fig. 3. The gameplay is designed using an adaptive algorithm with different levels. If the user is not able to solve the assigned task at the first level, then the subsequent level is made easy by altering some game elements (like a number of black dots or time limits) to maintain his or her level of satisfaction. Similarly, if the user completes the task very quickly then the next level is made more difficult to hold his or her interest in play. The system also provides tips and hints to the user throughout the play and feedbacks are dynamically generated by the system whenever required. A report based feedback helps to increase the level of interest as they can assess their own improvement at the end of each session. To adhere to the gaming standards, our gameplay introduces certain gaming aspects as follows:

- **Challenges.** Various challenges are included in the play to uphold the interest of the users. A timer is set at the start of each level and the user needs to complete the task within the time constraint. Also, the accelerometer data acquired from the Wii remote is used to restrict the user movement and generating warning when it accesses the predefined threshold value.
- **Animations.** The game effectively makes use of animations which scales down the cognitive load and thus facilitates learning.
- **Personalizing information.** A login system is employed in the system which helps in personalizing user information to boost their interest and consciousness towards the play.
- **Fantasy context.** Involvement of technologies like the computer and the Wii remote in the education process add a fantasy context to increase engagement and motivation of the users.

Our system thus successfully maps to the Bloom's Taxonomy of Learning Domain [20]:

- **Affective Domain.** The system manages to uphold the motivation and satisfaction level of the users by personalizing the game, introducing different in-game challenges and various feedbacks.
- **Cognitive Domain.** The "Facts" and "Stories" section impart the factual knowledge in form of textual, animations and audio-visual effects.
- **Psychomotor Domain.** The "Play" section helps in developing the motor skills to facilitate the proper brushing techniques of the users.

5 Research Methodology

Our research work primarily focuses on investigating the outcomes of learning in the cognitive and affective domain. It also includes an assessment process tracking the psychomotor development of the children throughout the play. Our study tries to address one overarching question and three sub-questions as follows:

Overarching Research Question. Does the proposed technology enhanced learning environment helps in improving children's outcome of learning?

Sub-research Question 1. Does the system accelerate cognitive learning in children?

Sub-research Question 2. Does the system arouse learning interest and improves learning outcome at affective domain?

Sub-research Question 3. Does the system help in developing psychomotor skills at the end of the learning process?

5.1 Study Design

An experimental study design was adopted using a pre-test and post-test interventions. Our focused group for user study was grade-3 and grade-4 students of a primary school in Tripura, India. The experimental design comprised of 80 students (grade-2 and grade-3 students) divided into two groups i.e. the treatment group and the control group (40 students each). The treatment group went through the experimental setup and completed their tasks as instructed (each participant were asked to play or interact with the system using the Wii remote). On the contrary, the control group was provided with a traditional classroom environment, where an instructor was teaching a group of students. In the case of the control group, the instructor did not use any technology-aided tools for teaching and they learned new concepts by listening to the instructor. Thus, both the groups are delivered same knowledge base about dental hygiene but experienced different environments of learning.

To ensure that the members of the two groups (treatment and control groups) are equivalent prior to the treatment, a matched random assignment technique was considered. This technique is adopted to normalize the assignments of participants to different groups based on characteristics like age and their familiarity with playing video games (which was recorded by interviewing the participants and their parents). A sample of the matched random sampling is shown in Table 1.

Table 1. Matched random assignment

Participant ID	Age	Played video games	Group
01	8	Yes	Treatment
02	9	Yes	Control
03	8	No	Treatment
04	8	No	Control
05	9	Yes	Control
⋮	⋮	⋮	⋮
80	9	No	Treatment

5.2 Instruments

Our user study comprised of different instruments used to assess the learning outcomes at various domains.

Cognitive domain. The pre-tests and post-tests interventions served as an instrument to investigate the outcomes at the cognitive domain for both the treatment and control groups. Before conducting the experiment, a pre-test was carried out on the topic of dental hygiene and the scores of each participant (treatment and control groups) were recorded. At the end of the experiment, a post-test was conducted depending upon the knowledge being delivered through the process. Some of the questions are listed as follows:

- Name the different types of teeth?
- What is the function of a molar and canine teeth?
- What is the cause of cavities?
- What is the name of the tooth model? (An animation of a tooth model is displayed on screen)

The pre-test and post-test results were analyzed to find whether there was a significant difference between the learning curve of the treatment and the control groups. An analysis of the variance was carried out by One-Way ANOVA using the SPSS statistical tool.

Affective Domain. The affective domain plays a transparent role in education. Emotional needs act as an unseen bridge between the physiological needs and self-realization or success. Therefore, it is equally important to take care of the affective domain in learning along with other factors like cognitive and psychomotor skills in children. To assess the affective domain in our study, we used an anecdotal report for each individual, a checklist and finally survey questionnaires.

Anecdotal report. The first instrument for assessing the affective domain was an anecdotal report which provided a brief narrative account of the participant's actions in intervals throughout the session. One of the observers present in the experimental area recorded a detailed description of each participant's activity carefully. The process was carried out for both treatment and control groups at three intervals each with a duration of 120 s. To provide a strong support to the anecdotal report created by the observers, we also recorded the experiments and captured users' reactions which were used later to interpret their behavior. During the observation, information was collected regarding how children communicated verbally or nonverbally. Physical gestures and movements, reactions towards the teacher or the game-based learning environment, and interactions with peers were also summarized. Figure 7 shows an example anecdotal record (record presented here shows a part of the collected data). Only observable actions were recorded in the anecdotal report and no generalization of the attitude and causes were written.

ANECDOTAL REPORT

Participant's Name: ***Meenakshi Das*** Played Video games: ***Yes*** *Date*: ***1/11/XX*** Age: ***8 years*** Group: ***Treatment*** Observer: ***Mitali Sinha***

Interval I: Meenakshi came into the classroom and took a seat. She wished the instructor "Good Morning". As the instructor gave instruction she looked at him. She raised a hand to ask a query as the instructor was explaining. She asked if she will be rewarded for her victory in the game.

Interval II: She sat in front of the computer and took the device in her hand. She started reading the instruction on screen and proceed as suggested by the instructor.

Interval III: At the middle of the activity, at times she exclaimed Wow!. She also informed the instructor "Sir, I want to know more about our teeth and how they catch cavities.

Fig. 7. A sample anecdotal report

Checklists. Checklists were used as our second instrument for information gathering. In this method, a number of specific traits or behavior was pre-defined by the researchers that are relevant to their work or motive of research. We designed our codes by studying various existing literature based on classroom observations [21, 22]. One of our observers sat with the checklist and recorded the actions of both the treatment and control groups. Each participant of both groups was observed at three intervals (120 s for each interval) and their behaviors were recorded positive or negative depending on their gestures and reactions. Table 2 shows the sample checklist of both treatment and control group at an instant.

Table 2. Sample checklist for recording behaviors of treatment and control group (Interval I).

Behaviors	Treatment Group							Control Group					
	1	2	3	4	5	…	40	1	2	3	4	…	40
Looking at Instructor/ Screen	✖							✖		✖			✖
Asking queries to Instructors									✖				
Looking outside classroom			✖	✖									
Feeling Sleepy	✖	✖	✖	✖						✖			
Talking with others (on irrelevant topic)	✖			✖									
Doing other works					✖		✖		✖		✖		
Sharing thoughts with peers after activity			✖						✖		✖		

Survey Questionnaire. The third instrument used in our study was the survey-questionnaire. Keeping in mind the young age of the participants the survey was conducted orally. The observers asked relevant questions to the participants in order to draw effective conclusions regarding their engagement and interest throughout the activity. The young participants were asked to describe the activity in their own words. Some of the survey questionnaires are as follows:

- How do you feel in learning by playing games?
- Did you enjoy studying?
- Would you like to learn and play again?

The accumulated reactions and comments were grouped as positive, negative and neutral. Comments including adjectives like “Awesome”, “Wow”, “Good”, “Superb”, “Fun”, and “Cool” were grouped as positive comments. While statements including words like “not fun”, “boring” etc. were grouped into negative comments. The neutral group comprised of statements that were irrelevant to the topic, providing neither positive nor negative views. Such group contained statements including words like “Okay”, “interesting but too easy”, “not my type” etc. The treatment and control group were compared against these three partitions of reaction (positive, negative and neutral) to investigate which group (treatment or control) had more positive comments. The group that showed higher positive comments were concluded as providing more engagement to the participants and thus better performance.

Psychomotor Domain. To investigate the effect of the proposed system in the psychomotor development of the children, the mean error (in performing correct gesture i.e. correct brushing technique) of each participant of the treatment groups were observed. The system keeps track of the psychomotor development of each individual and produces a report. This report is analyzed to assess whether the children developed the skills after going through the experiment.

6 Results and Discussions

6.1 Cognitive Domain

A pretest was carried out at the beginning to evaluate the internal validity of the experiment conducted, where both the groups were evaluated on their pre-knowledge about dental health and care. The test was based on the educational content to be delivered throughout the experimental process. The pretest questions consist of some basic to advanced questions regarding oral health. At the end of the experiment, a posttest was conducted to assess the learning outcomes of the participants. A One-Way Analysis of Variance (ANOVA) was formulated using the SPSS tool to evaluate the null hypothesis that there is no difference in the learning outcomes among children in the traditional learning environment and the proposed learning system ($N = 80$). Table 3 shows the mean of the difference between pretest and posttest results of participants in the treatment group ($M = 3.33$, $SD = 3.724$) and control group ($M = 1.68$, $SD = 3.362$). The mean value of 3.33 of treatment group depicts that the difference between the pretest and posttest results in the treatment group is more significant than the difference in the control group with the mean value of 1.68.

Table 3. Mean score table

Group	Mean	Std. deviation	N
Control	1.68	3.362	40
Treatment	3.33	3.724	40
Total	2.50	3.621	80

The assumption of homogeneity of variances was tested and found tenable using Levene's Test, F (1, 78) = 0.05, p = 0.943. The results of ANOVA was significant as shown in Table 4 with F (1, 78) = 4.327, p = 0.039. Thus, there is a sufficient evidence to reject the null hypothesis and conclude that there exists a significant difference in the learning outcomes of the children in the treatment and control group.

Table 4. One-way ANOVA test results.

	Sum of squares	df	Mean square	F	Sig
Between groups	54.45	1	54.450	4.327	0.039
Within groups	981.55	78	12.584		
Total	1536.00	80			
Corrected total	1036.00	79			

6.2 Affective Domain

Analysis of Anecdotal Records. To determine affective learning among the participants of the treatment and control group, we first performed a detailed analysis of the anecdotal records prepared by the observer. A report was produced for each participant in both treatment and control groups noting down their behaviors at three intervals. The sample individual report is shown in Table 5. Since the anecdotal report provides a detailed study of each individual, we broke down the observed behaviors into few set of behaviors (which was not pre-defined) for the sake of comparison. Mean score was calculated out of the three intervals for each individual participant. Again the mean scores of each participant in treatment and control group against enlisted behaviors were tallied and a final score for the two groups was presented. The final table of comparison between treatment and control group for the anecdotal report is described in Table 6.

Analysis of Checklist report. Our second instrument that is Checklists provides a means of quickly recording the presence or absence of a behavior amongst the participants. Unlike the anecdotal report, the checklist comprises of pre-defined rubrics on which we performed the comparisons. The checklist for the first interval for both treatment and control group is shown in Table 2. After three intervals the observations were compared and the final results were obtained by calculating the mean scores of treatment and control group towards the enlisted behaviors. This is shown in Table 7.

Table 5. Sample individual report at three intervals and their mean scores.

Behavior	Intervals			Mean (%)
	I	II	III	
Not paying attention to activity	✖		✖	33.33
Trying to understand the instructions	✖			66.67
Actively participating during the procedure		✖		66.67
Feeling bored	✖		✖	33.33
Interested in other topics not related to current	✖			66.67
Concentrating on others' works	✖	✖		33.33

Table 6. Comparison between treatment and control group for anecdotal report

Behavior	Treatment		Control	
	Mean	SD	Mean	SD
Not paying attention in activity	26.66	0.01	66.66	0.01
Trying to understand the instructions	73.33	0.02	30.00	0.03
Actively participating during the procedure	66.66	3.02	36.66	0.02
Feeling bored	29.99	0.03	36.66	0.02
Interested in other topics not related to current	50.00	3.33	46.66	0.02
Concentrating to others' works	29.99	0.03	30.00	0.03

Table 7. Comparison between treatment and control group for checklist report

Behavior	Treatment		Control	
	Mean	SD	Mean	SD
Looking at instructor/Screen	71.26	0.02	35.01	0.03
Asking queries to instructors	69.67	2.03	35.21	0.02
Looking outside classroom	21.23	0.02	50.53	0.03
Feeling sleepy	32.26	0.02	36.20	0.01
Talking with others (on irrelevant topic)	25.00	2.27	39.89	0.01
Doing other works	28.78	0.03	27.63	0.03
Sharing thoughts with peers after activity	68.82	0.03	25.43	0.02

Analysis of Survey Questionnaire. Further ambiguity check of the intended results was carried out by conducting a post-activity survey. In the post-activity survey, each participant of treatment and control groups were asked about their experience during the experiment. The answers of each participant were recorded and grouped into three categories i.e. positive, negative and neutral. Figure 8 shows the distribution of the comments for both the treatment and control groups. The graph depicts that the treatment group showed more positive response than the control group. Also, the control group produced a more negative reaction in comparison to the treatment group. A few participants' reaction in both the groups were neutral and showed the least interest in both cases. However, we found a major number of participants interested in learning in the treatment group and thus get some evidence of better performance in the treatment scenario.

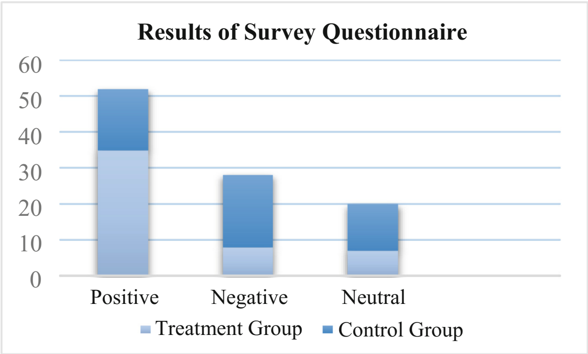

Fig. 8. Survey questionnaires results

6.3 Psychomotor Domain

The report generated by the system at each level corresponding to each individual is analyzed to check the improvement in psychomotor skills among the children. The system recognizes the number of attempts of each participant during the experiment and the mean error is calculated from the results. The Fig. 9 shows the comparisons between the mean error values at the first and last levels. As depicted by the graph, the mean error of many participants decreased eventually from the first level to the last level. This fact gives an evidence that the participants were making less error in the movement of the Wii remote and were successful in completing the levels in the game. Thus, we conclude that the participants showed improvement in developing the skills generating less mean error at the last level in comparison to the first level of the game play.

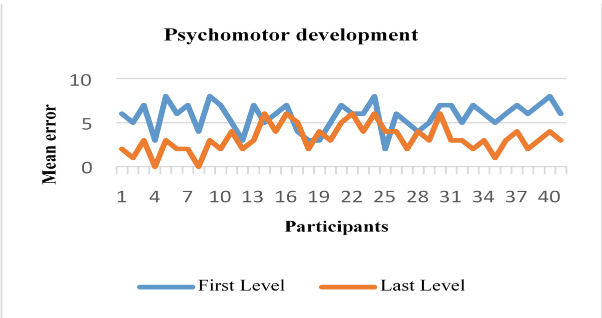

Fig. 9. Comparison between mean error values of the participants at end of the treatment

7 Conclusion

In this paper, we presented an enhanced learning environment which is guided by an intelligent tutoring system and investigated its effect on the learning outcomes of the children. Our work tries to address the areas of learning which is important but not very widely included in the education system's curriculum at present. We try to introduce an environment of the education system where we can enhance the outcomes of learning by increasing the interest and motivation of children towards learning new concepts. The proposed system was able to successfully deliver educational contents to the children and help in their cognitive development. By introducing the notion of the game and 3-dimensional contents in the application, the system was able to gain the attention of the participants thus improving the affective domain. Also at the end of the experiment, the participants were able to improve psychomotor skills by the technology-enhanced environment. Thus, the use of technology and enhanced interactions depicted better learning outcomes arousing the interests of young children in learning.

We now discuss a few limitations and future directions to our research work. The proposed system was developed to address primarily the dental health based contents. To generalize the educational contents proper care must be taken considering the target users else it would not be able to produce the desired results. Although our study depicted positive effects on learning, large-scale testing of the system with varying target groups is to be done in the future.

References

1. Montessori, M.: The Montessori Method: Scientific Pedagogy as Applied to Child Education in "the Children's Houses". Translated by Anne E. George. Heinemann (1937)
2. Papert, S.: Mindstorms: Children, computers, and powerful ideas. Basic Books Inc, New York (1980)
3. Resnick, M., Ocko, S., Papert, S.: LEGO, logo, and design. Children's Environments Quarterly, pp. 14–18 (1988)
4. Reiser, B.J., Anderson, J.R., Farrell, R.G.: Dynamic student modelling in an intelligent tutor for LISP programming. IJCAI **85**, 8–14 (1985)
5. Ritter, S., Anderson, J.R., Koedinger, K.R., Corbett, A.: Cognitive tutor: applied research in mathematics education. Psychon. Bull. Rev. **14**(2), 249–255 (2007)
6. Papadimitriou, A., Grigoriadou, M., Gyftodimos, G.: Interactive problem solving support in the adaptive educational hypermedia system MATHEMA. IEEE Trans. Learn. Technol. **2**(2), 93–106 (2009)
7. VanLehn, K., Lnch, C., Schulze, K., Shapiro, J.A., Shelby, R., Taylor, L., Treacy, D., Weintein, A., Wintersgill, M.: The andes physics tutoring system: five years of evaluations. NAAL ACADEMY ANNAPOLIS MD (2005)
8. Fossati, D., Di Eugenio, B., Brown, C.W., Ohlsson, S., Cosejo, D.G., Chen, L.: Supporting computer science curriculum: Exploring and learning linked lists with iList. IEEE Trans. Learn. Technol. **2**(2), 107–120 (2009)

9. Gertner, A.S., Van Lehn, K.: Andes: a coached problem solving environment for physics. In: Gauthier, G., Frasson, C., VanLehn, K. (eds.) ITS 2000. LNCS, vol. 1839, pp. 133–142. Springer, Heidelberg (2000). doi:10.1007/3-540-45108-0_17
10. Van Scoter, J., Ellis, D., Railsback, J.: Technology in early childhood education: Finding the balance. Northwest Regional Education Laboratory, Portland (2001)
11. Anderson, D.R., Pempek, T.A.: Television and very young children. Am. Behav. Sci. **48**(5), 505–522 (2005)
12. Barab, S., Thomas, M., Dodge, T., Carteaux, R., Tuzun, H.: Making learning fun: quest Atlantis, a game without guns. Educ. Tech. Res. Dev. **53**(1), 86–107 (2005)
13. Yien, J.-M., Hung, C.-M., Hwang, G.J., Lin, Y.-C.: A gamebased learning approach to improving students' learning achievements in a nutrition course. TOJET: Turkish Online J. Educ. Technol. **10**(2) (2011)
14. Ho, J.H., Zhou, S.Z., Wei, D., Low, A.: Investigating the effects of educational game with wii remote on outcomes of learning. In: Pan, Z., Cheok, A.D., Müller, W., Chang, M. (eds.) Transactions on Edutainment III. LNCS, vol. 5940, pp. 240–252. Springer, Heidelberg (2009). doi:10.1007/978-3-642-11245-4_21
15. Gerling, K., Klauser, M., Masuch, M.: Serious interface design for dental health: wiimote-based tangible interaction for school children. In: CEUR Workshop Proceedings, Vol 634 (2010)
16. Chang, Y.C., Lo, J.L., Huang, C.J., Hsu, N.Y., Chu, H.H., Wang, H.Y., Chi, P.Y., Hsieh, Y. L.: Playful toothbrush: ubicomp technology for teaching tooth brushing to kindergarten children. In: proceedings of the SIGCHI conference on human factors in computing systems, pp. 363–372. ACM(2008)
17. Piaget, J.: Piaget's theory of cognitive development. childhood cognitive development: the essential readings, pp. 33–47 (2000)
18. Mayer, R.E.: Multimedia learning. Psychol. Learn. Motiv. **41**, pp. 85–139 (2002)
19. Ryokai, K., Cassell, J.: StoryMat: a play space for collaborative storytelling. In: CHI 1999 Extended Abstracts on Human factors in computing systems. ACM. pp. 272–273 (1999)
20. Bloom, B.S., Krathwohl, D.R., Masia, B.B.: Bloom taxonomy of educational objectives. Allyn and Bacon, Boston, MA. Copyright© by Pearson Education (1984). <http://www.coun.uvic.ca/learn/program/hndouts/bloom.html
21. Roehrig, A.D., Christesen, E.: Development and use of a tool for evaluating teacher effectiveness in grades K-12. In: Shute, V., Becker, B. (eds.) Innovative Assessment for the 21st Century. Springer, Boston (2010)
22. Sawada, D., Piburn, M.D., Judson, E., Turley, J., Falconer, K., Benford, R., Bloom, I.: Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol. School Sci. Math. **102**(6), 245–253 (2002)