Smartphone Based Virtual Reality Systems in Classroom Teaching

-a study on the effects of learning outcome

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Abstract— **Virtual Reality (VR) has come up as a pinnacle of the ground breaking advances in computing power through developments in fields of electronics, software and mobile computing. It has been a topic of significant research and studies in recent years, given that 2016 is widely predicted to be the year where VR finds acceptability and affordability in mainstream consumer market. VR systems were first introduced to target entertainment and gaming, but numerous research and studies have shown its importance in educational purposes. There is a great potential in Virtual Reality Environments to serve as teaching aids in complementing and improving the education process. In spite of that, it is held back due to their bulky systems, complex setups and high cost, which limit their usage in versatile scenario. This study is being taken up to devise a solution that can address these problems using portable and simple VR setup with affordable hardware. The system used here takes help of Google's 'Cardboard' platform to provide the structure for Head Mounted Display while the display is provided by any smartphone that can be put inside the frame. This setup, other than being very easy to operate, is extremely cost effective and portable at the same time.**

This study aims to measure the feasibility of using the above mentioned VR system to improve the teaching process and the effect of this system on learning outcome. Through our experiments we intend to establish that such a setup is preferred by students for regular usage and improves their cognitive learning and participation.

Keywords — Virtual reality, Google Cardboard, Education technology, Classroom interaction.

I. INTRODUCTION

A. Virtual Reality and Education

Traditional education has always been language-based, conceptual and abstract creating a distance from practical learning, which results in a lack of deep and robust understanding of the subject matter [1]. The revised Bloom's Taxonomy of Educational Objectives [2] identify six levels of hierarchy in cognitive expertise, ranging from 'Remembering' at the low end, to 'Creating' at the high end. Common teaching processes are rarely found to address more than the first three levels of this hierarchy. These existing teaching methods of verbal fact delivery, visualization by chalk and blackboard or via projectors, are inherently static in nature that requires little or no student interaction. As a result, student attention deviates easily over longer periods of time. There is no scope for learning by first person experience.

VR technology offers significant benefits in this field by providing three experiences, namely *size, transduction* and *reification,* which are not available in real world but they are important in learning process [3]. *VR technology allows radical changes in the relative size of virtual objects and the students*. As in Winn's example, rather than bumping into a virtual wall, we can keep getting closer to it so that smaller and smaller details of the material from which it is made are revealed. At the other extreme, we can "zoom out" from the wall, out of the house, the city, the country and the planet if we want. *"Transduction"* is conveying information that are not readily available to human senses. For example, intensity of color being used to portray level of radiation in virtual environment. *"Reification"* is the process of creating these perceptible representations attained by changes in size and transduction. It gives first-person access to experiences that students could not otherwise have.

In spite of the amount of research, the use of VR in actual classrooms were limited. This can be attributed to the high cost of hardware that was beyond student or institutional budgets. Hardware and software support was also a hit and miss case due to fragmented and unstable market consisting of numerous small companies competing without collaboration.

In our experiment we set up a system that uses Virtual Reality to aid and improve the daily classroom teaching process. For achieving this, the system has to be cost effective so that it can be used individually by every student. Apart from this, the setup has to be portable to facilitate continued usage without being a hindrance to normal flow of classwork. This is an important factor to achieve acceptability among students and teachers for long term usage. The system is based on Google Cardboard. It is a Virtual Reality (VR) platform developed by Google for use as a head mount with a smartphone [5]. Named for its fold-out cardboard viewer, the platform is intended as a low-cost system to encourage interest and development in VR applications [6]. It was announced in Google I/O 2014 developers' conference. Users can either build their own viewer from simple, low-cost components or purchase a pre-manufactured one costing as low as 10$. As found in our study,

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ninety-nine percent of students had their own smartphones. So we decided to follow (Bring Your Own Device) BYOD approach for the phones to be used inside Cardboard. The experiment was conducted over two groups of students to measure the effects of using a VR system in contrast to using traditional systems in classroom. The affordance and acceptability of VR system was taken into consideration. The response and performance of students were evaluated and contrasted using set of carefully selected scientific methodologies including questionnaires and objective tests.

II. Literature Survey

A. *Existing work on Virtual Reality for Education*

VR is an intriguing technology. When to use it and when not to use it are some of the confusions surrounding it. Pantelidis, V. S. (2010) suggested a model describing when and where to use VR [7]. The author suggests VR is helpful in any scenario that requires simulation, realism and immersion.

An extensive survey of research and educational uses of virtual reality, conducted by Youngblut (1998) presented a very positive picture of the potential [4]. Youngblut found that there are unique capabilities of virtual reality, and the majority of uses included aspects of constructivist learning (1998, p. 93). The majority of the teachers in the studies reviewed said they would use virtual reality technology if it were affordable, available, and easy to use for students and teachers (1998, p. 101). But the practical questions bring forth the drawbacks in three main areas namely cost, hardware support and lack of proper software development tools (1998, p. 104). The estimated cost of hardware starts from $10,000 to $25,000, which is beyond most elementary, middle and high school budgets. The instability of VR hardware market at that time was also a concern for acquiring devices and continued after sales support for hardware (1998, p. 105). Software compatibility and availability of proper unified development tools were another major roadblock.

From software viewpoint, there has been a number of significant VR environments that were developed for various educational purposes. Some notable works are Vicher [8] and Mass Effect [9]. But once again, there exists major roadblocks in their everyday usage. These systems are highly subject oriented with static content. Moreover, the hardware cost and portability problems mentioned above is applicable to these systems also.

B. *Existing works on Google Cardboard*

There is no significant research work where Cardboard is exclusively used as a hardware platform. The only notable use is found in Expeditions Pioneer Program [10]. This is a pilot program undertaken by Google in very few cities around the world where selected schools are provided Cardboard viewers, smartphones and tablets to set up a virtual guided journey consisting of various archaeological or important places like Coral Reefs, space journey, galleries and museums, etc. The students wear their viewers and look into the 3D scenes while the teacher guides them using a tablet device, highlighting various details and editable notes embedded in the scenes. But being a proprietary and closed access program, the research details available from it are almost zero. Moreover, the program is carried out in few cities in western countries and there is no sign of it extending into developing countries.

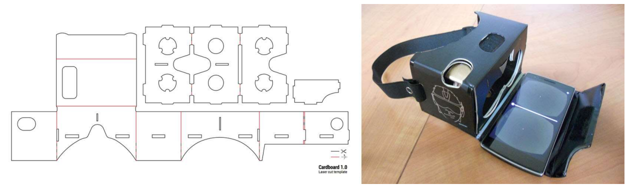

Figure 1: Schematics of Google Cardboard [5] and an assembled Cardboard setup used in experiment

III. Proposed System

Cardboard viewers are either procured from market or cut out of cardboard. In case they are bought, prices are around only Rs.200 per piece. During classroom teaching, whenever teacher wants to display a content, the students are asked to put on their viewers and browse to the corresponding content inside the app. When the content is displayed on screen, each student can individually look around the scene and its details in own pace and own perspective irrespective of how others are viewing.

A. *Architecture*

The system is a combination of hardware and software components. The viewer frame is provided by Cardboard which holds the smartphone. The viewer has a magnetic button or capacitive ribbon on the side. It is used to give simple input signals to the smartphone to select objects on screen. The viewing screen and processing power is entirely provided by the smartphone. A minimum requirement of 1GB RAM, 4 inch + screen and capable GPU is fulfilled by almost all smartphones nowadays, even costing as low as Rs.6000. The third component is the Cardboard compatible app that splits the display into two and applies distortion correction to produce a stereoscopic 3D scene. It displays various contents such as 3D models and panoramic photos and videos with spatial sound.

B. *Implementation*

Google provides three different SDK (Software Development Kit) to make Cardboard apps. This includes Android SDK, Apple iOS SDK and a Unity SDK. All three platforms are equally popular and there is no lack of support and compatibility. The underlying standard is OpenGL, which is widely accepted popular high performance industry standard. The Android app is made using Java language corresponding to JDK (Java Development Kit) 1.7, using Android SDK version 24. The user is required to open the app on phone and then put the smartphone inside cardboard viewer. After that the viewer can be held in front of eyes or worn on the head using a strap. A cursor like reticle is present inside the scene which moves along the direction user is facing. Navigation inside the app is handled by head tilting or pressing virtual buttons by positioning the reticle and clicking the external input mechanism in Cardboard viewer.

IV. Experimental Setup

The primary research questions that had to be answered were listed down. Is the proposed VR system affordable, such that

Figure 2: User wearing a Cardboard viewer with attached smartphone.

every student can use it individually? Do the students agree that the hardware is easy to use and portable? And are there any significant improvements in student performance upon using VR system in classroom learning?

A. Sample

The experiment for this study consisted of sessions for two groups of participants, 20 in each. The participants selected for this study were students of third year B. Tech of NIT Agartala. The sessions were on the topic 'Micro-controller and Arduino Boards' in the Human Computer Interaction (HCI) lab. The participants were asked for their consent at the beginning of the session. The assignment of the participants was done by the method of random matching [11], [12]. Through this process the participants of the two groups were matched based on the prior knowledge on the topic that was identified through the results of the pre-tests. This was achieved by selecting the first two highest scoring students and assigning them to group A and B respectively. In the second round of assignment, the order was reversed to B and A respectively. This was repeated until no more participants were left, each time alternating the order.

B. Procedure

Sessions for the two groups were conducted in the following manner: Control Group A: Traditional teaching using whiteboard, slides and projector. Treatment Group B: Teaching complimented by usage of VR for 3D and immersive content delivery. For group A, sessions consisted of vocational teaching by the instructor. This was accompanied by slides presented via projector whenever necessary. For group B, the primary teaching was similar vocational fact delivery by the instructor. But instead of slides and projector, VR system was used to show contents in 3D and panoramic views. With embedded notes and highlights in the scenes. The students were asked to bring their smartphones everyday with the required app installed. The cardboard viewer was provided in the lab whenever required. Every time a VR content was to be displayed, students were asked to put on their systems and go through the content.

C. Data Analysis

For every session, the students were subjected through the standard model of two tests, before and after sessions. The pre-test indicated how much understanding the students were having before the start of session. Post-test results present their understanding levels after the session. The performance gain is calculated by the difference in pre and post test results. This was continued for two months, two sessions per week, for a total of 16 sessions. The average results for each group are listed below.

TABLE 1 : PERFORMANCE GAIN OF GROUPS

Session Number	Performance Gain	
	Group A	***Group B***
1	6.25	5.5
2	5.75	5.25
3	7.0	6.50
4	6.75	6.5
5	3.5	5.5
6	6.0	7.5
7	5.5	5.0
8	7.75	8.0
9	4.25	6.50
10	5.75	7.50
11	6.25	7.25
12	8.75	9.0
13	6.75	5.75
14	4.50	6.75
15	3.25	5.0
16	2.75	2.5

The treatment group B were given a set of questionnaire twice during the two-month period. Once halfway through the experiment, and finally at the end of 16 sessions. This was done to capture any variations in response during the long time period. The questionnaire consisted of four statements to be rated using a scale of 5, 4, 3, 2, 1 for "Strongly agree", "Agree", "Neither agree nor disagree", "Disagree" and "Strongly disagree".

TABLE 2 : RESPONSES TO QUESTIONNAIRE

Question Number	Mid-session Response	End-Session Response
1	4.3	4.7
2	5.0	5.0
3	4.1	4.6
4	3.9	3.8

V. RESULTS ANALYSIS

Students under treatment group B were initially slightly behind the group A. But as the sessions progressed, they quickly caught up. In the end, the average performance of Group B was significantly better than Group A. This can be attributed to the

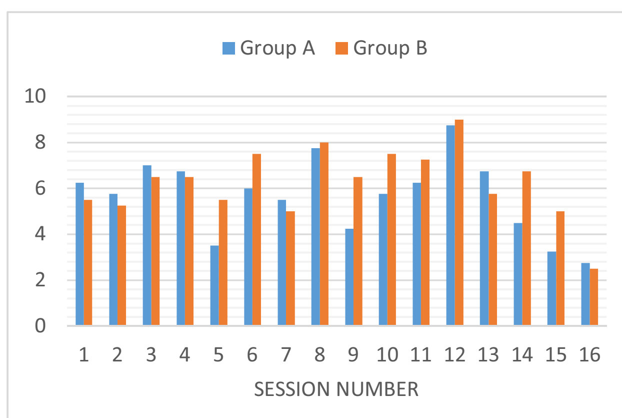

Figure 3: Comparison of Performance Gain Among Two Groups

fact that students were not initially comfortable with using VR system, but they got used to it as more sessions were conducted. The final results show a promising scenario that treatment group B had a better overall performance than control group A. The lower value of variance and standard deviation of Group B performance gain assert the fact that Group B students performed better more consistently.

TABLE 3: STATISTICAL PROPERTIES OF PERFORMANCE DATA

	Group A	Group B
Mean	5.671875	6.25
Std. Deviation	1.657606	1.52206
Variance	2.747656	2.316667

The response to questionnaire given to Group B was overall positive. Statement 2 got an extreme positive rating among every student, whereas Statement 4 acquired the lowest rating. There was a sharp increase in rating of Q1 between mid-session and end-session evaluation. This indicates that students became more comfortable as they got used to the system. Q2 got a positive rating as students agreed to the fact that the VR system was extremely portable. For Q4, the operational complexity of the system was not a problem as most students were familiar with Android OS and they got more accustomed as session progressed. Q5 got the lower rating as displaying 3D contents on mobile displays is not always optimal, but it was acceptable for most.

TABLE 4: AVERAGE RATINGS FOR QUESTIONNAIRE

Question Number	Question	Avg. Response
1	Using a VR system made the learning experience for interactive and interesting.	4.50
2	The VR system is portable and easier to carry around than a personal laptop.	5.00
3	The system comprising of viewer and mobile app was easy and intuitive to operate.	4.35
4	Performance and quality of the VR system in displaying contents was acceptable.	3.85

VI. DISCUSSION

The results obtained from the experiment shows how usage of VR system affected the knowledge gain in the treatment group of students. The feedback questionnaire provided to Group B students served as an indication of students' response to the new teaching system in class. This is essential in evaluation of changes and modifications to better suit their needs. Coming to our primary questions, we can formulate our answers from the experimental observations.

Is the proposed VR system affordable, such that every student can use it individually? In our setup, each Cardboard viewer cost less than Rs.300. For a group of 20 students, this is roughly Rs.6000. Being a one-time expenditure, this is easily affordable for an institute.

Do the students agree that the hardware is easy to use and portable? The viewer once assembled is extremely easy to use as the only interaction is to put the smartphone inside it. Most actions are intuitively handled by single click or head gestures. As per students' review, portability got a rating of 5 out of 5, whereas ease of use got 4.35 out of 5.

Are there any significant improvements in student performance upon using VR system in classroom learning? The data collected during the sessions shows that student group using VR system had a significant increase in performance as experiment progressed. This confirms that VR can be used effectively for increasing student performance and participation.

VII. CONCLUSIONS

The experiment along with the proposed low cost VR setup shows how Virtual Reality environments can be used in educational field with minimum expenditure. This is a step in the direction of bringing immersive and realistic learning environment to students and teachers in traditional classrooms. The study in this paper could act as an important precursor for researchers looking into the field of VR in classrooms. For further work, there is scope for in depth measurement of students' activities and attention levels via analytics systems implemented in VR itself. The experiments conducted above can be performed on a bigger group of students for longer duration to find out minute effects. We are envisioned that the use of such mobile based low cost VR would not only improve the teaching-learning process, but also increase student interest.

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