The Third International Conference on Design Creativity (3rd ICDC)
ISBN 978-1-904670-60-5
Bangalore, India, 12th-14th January 2015

ROLE OF IMMERSIVE VIRTUAL REALITY IN FOSTERING CREATIVITY AMONG ARCHITECTURE STUDENTS

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Abstract: Spatial reasoning is the a fundamental skill for in the profession of architecture. Space visualisation and it's mental manipulation is required to conceptualise a design. An architect with better spatial ability would be able to harness the ability better and thus be more creative in the solutions he/she proposes. However, new entrants to the architecture education find it difficult to imagine and work with 3D space. Instructors often are at odds when it comes to explaining the topics like projection of solids, regeneration of solids, etc to first year students. Students are unable to leverage their knowledge effectively and solve for challenges creatively. The problem is not with aptitude but rooted in current methods of teaching. In this paper, we propose a learning platform which is anchored immersive virtual reality technology. This paper hypothesizes the platform's role in enhancing spatial ability among architecture and engineering students, and presents the controlled expreiemnt and subsequent evaluation carried out to test the hypothesis.

Keywords: *Virtual Reality, Architecture Education, Spatial Ability*

1. Introduction

The generation of architectural form is by definition a creative activity. The creative solutions proposed by an architect are, to a great extent, a product of his/her "spatial ability". When an architect builds a 3D mental representation from orthographic projections, he/she is employing his/her spatial ability. The reciprocal skill i.e. deriving multiview drawings of imaginary 3D objects uses the same ability. Literature suggests that spatial ability comprises two components: spatial orientation and spatial visualisation (Clements & Battista, 1992; Pellegrino et al., 1984; Sorby, 2009). Former involves changing self's viewpoint mentally while keeping objects fixed in space, latter involves mentally visualizing, moving and transforming objects.

Results from a longitudinal study (Wai et al., 2005) confirm longstanding speculation in the psychological sciences that early spatial ability affect creativity and scholarly achievements at later stages of life. One could therefore also say that an architect with better spatial ability would be provide more creative solutions. Thus, cultivating spatial ability among architecture students is imperative for enhacing their creative thinking.

It (Duesbury and O'Neil, 1990) has been demonstrated that "spatial ability" can be improved through practice, especially when learner is allowed to see the relationship between the 2D and 3D features of objects. A particular instructional intervention (Potter and Van der Merwe, 2001) carried out over a 20-year period has demonstrated that spatial ability influences academic performance in engineering, and can be increased through instruction focused on using perception and mental imagery in three-dimensional representation.

Thus, if students are placed in 3D space while teaching them about space manipulation, then their spatial ability can be triggered earlier. Systems like CAD provide the students and instructors with precise and appealing representations of the object to be designed, but they require complex and non-intuitive actions for representing these objects. To achieve enhancement in spatial and creative ability, it appears suitable to develop computational systems that would require simple and intuitive actions to produce 3D virtual representations of the object to be designed (Bonnardel, Nathalie, and Franck Zenasni, 2010). Immersive virtual environments have the potential to give users a better understanding of the three-dimensional space they inhabit, in comparison to cnvetional 2D displays (Pausch, Shackelford & Proffitt, 1993). They are known to capture and convey the look and feel of 'real' surroundings to convince some part of the participants' brains that they are physically in this other world (Aldrich. C, 2009). This paper hypothesises that by using virtual reality to explain space and related concepts, one can foster spatial ability and consequentially creativity among architecture students. To demonstrate this, an instruction platform anchored in immersive VR was developed, which imparted knowledge on concepts of engineering drawing/architectural graphics.

2. Related Work

The course of engineering graphics is an introductory course for architecture, engineering and design students where they acquire and futher their spatial ability (Bishop, 1978). The course imparts knowledge on concepts of projective representation of objects, combining different perspectives to regenerate an object, concept of measurement in different views, an object's topological relationship with other objects, etc.

To enhance students' learning at the subject, we designed a learning platform (Pandey et al., 2014) which makes use of the virtual reality (VR) technology. The platform is used to instruct on the topics of projection of solids and section of solids for the course of engineering graphics. To this end, we have simulated hexagonal square pyramids and prisms, which are commonly encountered geometric objects in the instructional material. Projections of the simulations are mapped on vertical, horizontal and profile planes. The simulations can be manipulated i.e. scaled, moved and rotated freely along the three axes of rotations using :

1. Gestures, when the student is wearing a HMD for an immersive learning environment
2. Keyboard and mouse, for use of tool on desktops, laptops or computer screens
3. Changes to the simulations and their projections are updated simultaneously. The conventions followed in engineering graphics for projection lines and labels are used in the prototype

3. Empirical Study

Our hypothesis regarding the effectiveness of the learning platform was that immersive VR can significantly improve the performance of students in learning projections of solids.

3.1. Procedure

A small experiment was conducted to assess the achievement of learning objectives with the tool. The experiment comprised of 46 participants, drawn from among the first year students of architecture department of Royal Group of Institutes, and IIT Guwahati. This ensured a versatile pool of students for the experiment, with students participating from all branches of engineering, architecture and

design. Participants were all aged between 18 to 20 years old. They had all received formal classroom instruction on the topic of projection of solids, and attended tutorial sessions for the same.
Each participant took the standardized PSVT(Bodner & Guay, 1977) test. Depending on the test score and academic performance in the course of Architectural Graphics, participants were divided into experimental and control group. Former comprised 24 participants, latter consisted of 22 participants. Average grade for both groups was equal, and standard deviation was low. Instruction material for the experiment was developed by the research team with due help and verification from course instructors. The controlled group was instructed on the topic through traditional classroom instruction in form of lecture slides.

Experimental Group was taught using the VR prototype. We provided the experimental group with small tasks which increased in difficulty as they advanced. These tasks followed the order provided in textbooks with the added flexibility of reversibility. The order of tasks was -

1. Select a solid of your choice from the tool.
2. Identify the axis of the solid
3. Orient the axis such that it becomes perpendicular to the vertical plane
4. Identify all possible orientations in which the solid is perpendicular to V.P
5. Orient it such that it becomes parallel to both vertical and horizontal plane
6. Identify all possible orientations in which solid is parallel to both H.P and V.P
7. Orient the solid such that it forms 45 degrees with both H.P and V.P
8. Identify all possible orientations for the above angle
9. Reset the solid to it’s original orientation i.e. axis perpendicular to H.P.
10. Identify the projections it would form on both planes.
11. Next, rotate it around it’s axis only in one degree of freedom
12. Observe the changes in projections.

3.3. Knowledge Based Quiz

The treatment and the control group took a knowledge based quiz related to the topic of projection of solids. Quiz comprised total 12 questions, including sub-parts to the main questions. 4 out of the 12 questions were subjective in nature. These required participants to draw projections of solid on the vertical plane and horizontal plane. The knowledge test and weightage for each question was prepared with the help of an architectural graphics instructor at IIT Guwahati.

3.2. Technology Acceptance Model (TAM)

Apart from measuring the tool’s effectiveness, attitudes of students towards the learning tool was also evaluated using the Technology Acceptance Model (TAM) (Venkatersh & Davis, 2000). To this end, a posttest questionnaire was given to the students in experiment group to evaluate their attitude towards using the tool for learning.

TAM explores users' acceptance of a technology based on user attitudes, and is linked to Social Cognitive Theory by two key constructs to determine user acceptance – perceived usefulness (PU) and perceived ease of use (PEOU) (Davis, 1989). As per TAM, perceived usefulness is determined by perceived ease of use. In addition, both these variables can be affected by various external variables which describe user characteristics, system features, and the setting in which the system is used.

External variables used in the study are :

1. Interaction and Imagination - Virtual reality has been defined as I3 for ‘Immersion–Interaction–Imagination’ (Burdea & Coiffet, 2003). Past studies have shown a significant impact of interaction and imagination on perceived usefulness and perceived ease of use in immersive virtual reality learning environments (Huang et al., 2010). Thus, all three features should be considered while measuring learners’ attitudes.

2. Motivation to use the VR tool - Original TAM model takes into consideration extrinsic motivation in the form of perceived usefulness. Motivation was taken into account because our user research showed students to be demotivated towards the subject.
3. Appropriateness of content - This parameter was considered to determine the difficulty faced by students in understanding the content developed and taught through the tool.

The questionnaire consisted of the aforementioned variables i.e. perceived usefulness, perceived ease of use, attitude towards using this tool (ATU), intention to use (ITU), interaction and imagination features of virtual reality, motivation to learn as Likert items. A five point scale was used where (1) denoted "strongly disagree" and (5) denoted "strongly agree". Questionnaire also collected biographical information on gender, age, school grade, frequency of computer use, frequency of computer gaming, enjoyment of computer games, interest in learning engineering drawing/architectural graphics. Few open ended questions were posed to collect participants' opinions/comments about positive and negative characteristics of the VR tool.

To measure the questionnaire's internal consistency, Cronbach alpha was calculated for each of the five variables. Cronbach alpha should be greater than 0.7 for constructs to be reliable. The obtained Cronbach alpha values for each variable was between .71 to .81 with overall being .803.

4. Results

Data were analyzed using SPSS version 20.0.

4.1. Effectiveness as a learning tool

Average score of the experimental group is 15.8 and that of controlled group is 11.4. Standard deviation of marks from the mean was 7.1 for experiment group, while that for control group was 6.1. On applying the independent t-test, independent t-tes, p-value was found to be 0.016, which is less than the required p of 0.05. The analysis of the quiz scores gave us a significant difference. This was despite the sample size being small. We feel, that with more participants we would get markedly better results. Also, the experiment was conducted over a 2 weeks . We feel that if the tool is used for the entire duration of the course then results would show further difference in perception and performance in the course. However, it can be established that immersive virtual reality improves spatial ability by improving understanding of topics from the engineering graphics course.

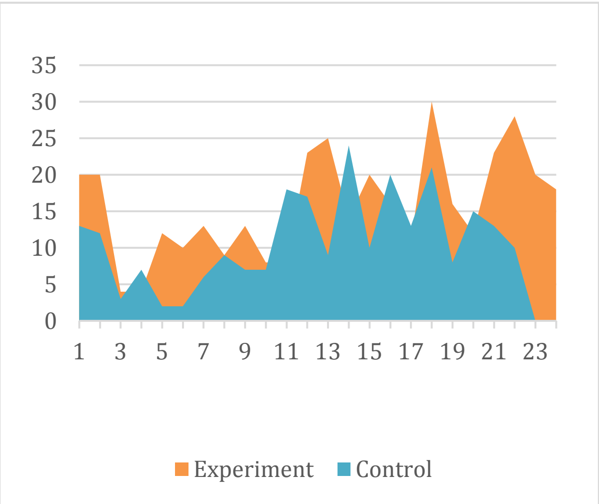

Figure 1: Plot of quiz scores

	Experiment	Control
Participants	24	22
Mean	15.8	11.4
Standard Deviation	7.1	6.1
Median	15	10
P(T<=t) one-tail	0.016788709	

Table 1: Results of t-test on quiz scores

4.2 Acceptance of VR technology

Through stepwise multiple regression analysis, we checked the effect of external variables (imagination, interaction, and motivation) on the variable of perceived usefulness and perceived ease of use. The relationships obtained between different constructs of TAM can be seen in figure 2. Results for the same are plotted in table 2. It can be seen that impact of Interaction and Motivation is present on both Perceived Usefulness and Perceived Ease of Use. Construct for imagination and motivation were consistently ranked high by users in the questionnaire designed. This shows that in immersive virtual reality, learning, imagination strongly impacts the motivation to learn.

Table 2 : Means and standard deviation of TAM parameters

Dependent Variable	Independent Variable	Beta Value	R^2
Perceived Usefulness	Interaction Motivation	.523 .364	.226* .196*
Perceived Ease of Use	Interaction Motivation	.386 .376	.141* .149*
Motivation	Imagination	.403	.162*
Attitude Toward Using the Tool	Perceived Usefulness	.462	.213*
Intention to Use	Attitude toward using the tool Perceived Usefulness	.440 .493	.194* .243*

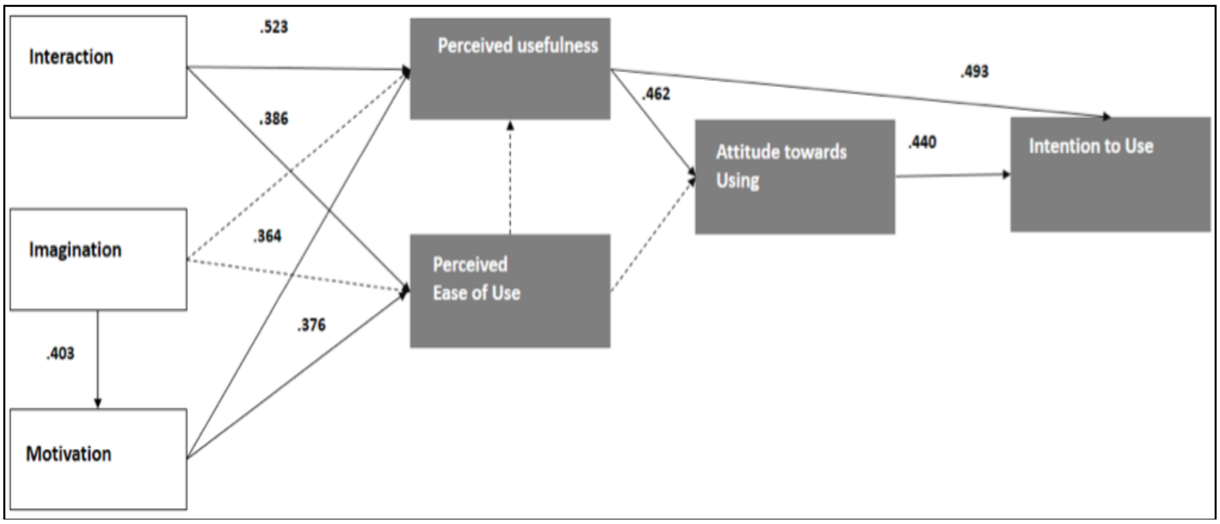

Figure 2 : Model of Learner's attitude towards VR learning tool

Parameters	Means	Standard Deviation
PU	4.374583	0.420569
PEOU	3.847083	0.722017
ATU	4.528333	0.404493
ITU	4.319583	0.585413
Interaction	4.334583	0.451413
Imagination	4.58375	0.371552

Motivation	4.167083	0.614446

Table 3 : Results of Regression Analysis

Since the sample size was small, some of the results of previous studies could not be established . Thus, we could not prove conclusively the effect of the variables, shown by dashed lines in figure 2. Finally, results (Table 3) from TAM show Perceived Usefulness (4.37), Attitude towards using (4.57) and Intention to use tool (4.31) to be quite high indicating strong acceptance of tool for learning.

4.3 Participants' Comments

Most students expressed their desire to use the tool in future.Users agreed to having enjoyed learning from the tool. Quoting a particpant, who considered himself to be weak at the course, "I am a student who is very weak in E.D i.e. I often get scared about imagining and visualizing 3D figures. However, I believe if there is a proper guide who can explain me concepts side-by-side with this software, I can really get over my fear and learn engineering drawing." Another particpant said, "Some topics are a bit difficult to understand and imagine, even if instructor tries his best to explain on board and via slides. … this tool will make learning very easy and save time of students." Another particpant mentioned that she would have understood projection of solids better had she received instruction through this tool.

5. Conclusion

This study shows the immersive VR can be used as a teaching tool for the course of engineering graphics, and for enhancing spatial ability of students. This would subsequently enable them to think of more creative solutions. Our study also demonstrates that a well-planned, systematic approach supported by a carefully designed strategy, is very important to ensure new technology is embedded and integrated strategically into the curriculum effectively.

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