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Virtual Simulation Based Instruction: An Effective Means To Improve Learning of Chemistry At Higher Secondary Level

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Abstract:
This study explores the effectiveness of Virtual Simulation based Instruction (VSI) as an innovative pedagogical tool for enhancing the learning of chemistry among higher secondary school students. Employing a pre-test, post-test non-equivalent groups design, the research involved 100 Class XI students from a higher secondary school in Kottayam District, India. Participants were divided into two groups: one (n=50) received instruction through VSI, while the other (n=50) was taught using the traditional Activity Oriented Method of Instruction (AOMI). Over a 20-day instructional period covering the topic "Organic Chemistry – Some Basic Principles and Techniques," student achievement was assessed using a researcher-developed test. Statistical analyses including t-test and ANCOVA, indicated that students in the VSI group demonstrated significantly higher achievement than those in the AOMI group across all measured domains. The results affirm VSI as an effective strategy for improving conceptual understanding and application in chemistry at the higher secondary level. These findings have valuable implications for educators and curriculum developers aiming to integrate virtual technologies into science education.

Keywords: Virtual Simulation, Chemistry Education, Learning, Higher Secondary School, Activity Oriented Method, Educational Technology.

INTRODUCTION

"Education is the most powerful weapon which you can use to change the world" (Nelson Mandela).
This profound statement underscores the transformative potential of education in shaping individuals and societies. Education, whether conscious or unconscious, is a multifaceted psychological, sociological, scientific, and philosophical process aimed at the holistic development of an individual. It serves as a potent instrument for social transformation and national progress, equipping individuals with the requisite knowledge, skills, and attitudes to realize their full potential and contribute meaningfully to their communities and the nation. In essence, education empowers individuals to adapt effectively to the dynamic demands of their physical, social, and spiritual environments.
Virtual simulation has emerged as a transformative tool in education, offering immersive and interactive learning experiences that enhance students' understanding of complex concepts across various subjects.

Virtual Simulation based Instruction represents a transformative approach in chemistry learning, harnessing the capabilities of virtual reality and simulation technologies to enhance both the teaching and learning processes. This innovative method allows students to interact with complex chemical concepts and laboratory techniques within a safe, controlled, and immersive virtual environment. Key aspects and benefits of employing VSI in chemistry education include:

- **Virtual Chemistry Labs:** A significant application of VSI is the simulation of laboratory experiments. Students can conduct a wide array of virtual experiments, ranging from basic titrations to complex organic syntheses, without the limitations of physical lab resources or the risks associated with handling hazardous chemicals.
- **Real-Time Feedback:** Virtual simulations can provide immediate feedback on students' actions, enabling them to understand the consequences of their decisions and learn from mistakes in a risk-free setting. This immediate feedback loop enhances the learning process and fosters self-directed learning.
- **Scalability and Accessibility:** VSI can make high-quality chemistry education more accessible to students who may lack access to well-equipped physical labs due to geographical, financial, or other constraints. Virtual labs can be scaled to accommodate large numbers of students, thereby breaking down barriers to education.

NEED AND SIGNIFICANCE OF THE STUDY

This innovative instructional strategy holds the potential to cultivate creative and scientifically talented citizens who can effectively address the demands of the future. Science and technology have firmly established themselves as powerful forces shaping the trajectory of our world. Joyce and Weil (2003), in their seminal work "Models of Teaching," define teaching models as instructional designs that describe the process of creating specific environmental situations that encourage students to interact in ways that lead to desired behavioral changes. Teaching models are invaluable for guiding student activities and developing specific teaching aids. To ensure students acquire appropriate competencies and skills, structuring the learning environment effectively is crucial. This necessitates the evolution of appropriate pedagogical practices that align with children's interests and needs (Rac, 2004). In chemistry education, strengthening the connection between theory and practice through innovative instructional strategies is paramount, particularly in relation to real-world applications. Recognizing this need, a teaching strategy capable of enhancing students' effective learning was sought, leading to the selection of Virtual Simulation based Instruction for this study. Drisya (2014) tested the effectiveness of Interactive compensatory Model of learning on Achievement and Interest in Chemistry of students at secondary level. By using interactive compensatory model of learning, we can provide different learning experience to the secondary school students. Baby (2013) in the study ‘Developing a Computer Assisted Instructional Package for Learning Organic Chemistry at Higher Secondary Level’ developed a Computer Assisted Instructional Package and measured its relative effectiveness with the prevailing Activity Oriented Method among the students of Kerala. Elizabeth (2011) conducted a study on the effectiveness of Generative Learning Model on achievement in chemistry at secondary school level. It is hoped that the study would contribute some highlights towards new strategies of teaching especially towards generative learning model. Pooja (2011) evaluated the effectiveness of EDI Model on Achievement in Chemistry at Secondary School Level. It is hoped that the study would contribute some highlights towards new strategies of teaching. Chandran (2008) studied about the effectiveness of

symbol Representation Technique on achievement in chemistry at secondary school level. It is hoped that the study would contribute some highlight towards new strategies of teaching. Rahul (2010) study on the effectiveness of phase of Edgar Dale's cone of Experience on achievements in chemistry at secondary school students. So the study envisages the comparison of phases of cone of Experience in teaching Chemistry.

We are currently witnessing a transformative phase in education, characterized by fundamental attempts to develop novel instructional theories based on the evaluation of extensive research across various domains to address existing challenges. Educational institutions are actively adapting to the evolving teaching-learning environment, which places increasing demands on them in terms of responsibility and accountability. At the higher secondary level, science teachers predominantly employ the lecture method and the lecture-cum-demonstration method. Virtual Simulation based Instruction (VSI) presents a unique and compelling alternative, particularly well-suited for science subjects due to its powerful potential to develop scientific skills. Effective communication about science through engaging methods like VSI can enhance the level of scientific understanding and subsequently lead to higher achievement in learning science.

HYPOTHESIS OF THE STUDY

It was hypothesized that Virtual Simulation based Instruction is more effective than Activity Oriented Method of Instruction on Learning in Chemistry at higher secondary school level.

OBJECTIVES OF THE STUDY

The objectives of this study were:

1. to determine the effectiveness of Virtual Simulation based Instruction on Learning in Chemistry among higher secondary school students.
2. to determine the effectiveness of Activity Oriented Method of Instruction on Learning in Chemistry among higher secondary school students.
3. to compare the effectiveness of Virtual Simulation based Instruction with that of Activity Oriented Method of Instruction on Learning in Chemistry among higher secondary school students.

METHODOLOGY

The study employed the **Experimental Method**, which was deemed most suitable for achieving the research objectives. The research design used was the **Pre-test Post-test Non-Equivalent Groups Design**. The study was conducted on a sample of 100 students from Class XI of Our Lady of Lourde's Higher Secondary School, Uzhavoor, located in the Kottayam District of Kerala, India. The sample comprised two intact classroom groups. One group (n=50) was randomly assigned as the **Experimental Group** and received instruction through Virtual Simulation based Instruction. The other group (n=50) served as the **Control Group** and was taught using the Activity Oriented Method of Instruction. Prior to the intervention, both groups were administered a **Pre-test** using the researcher-developed Test on Achievement in Chemistry. Following the 20-day instructional period, the same test was administered as a **Post-test** to both groups. The pre-test and post-test scores were then subjected to appropriate statistical analysis to compare the effectiveness of the two instructional methods.

TOOL AND MATERIALS USED

The tool used for data collection in this study was a researcher-developed Test on Achievement in Chemistry. This test was specifically designed to evaluate students' comprehension and ability to apply concepts related to a selected unit in Organic Chemistry, ensuring alignment with the instructional content delivered during the study. The tool employed for data collection in this study was:

- **Test on Achievement in Chemistry**

The instructional materials employed included two distinct sets of lesson plans. For the experimental group, lesson plans were developed based on virtual simulation-based instruction, integrating digital simulations as the central teaching approach. In contrast, the control group utilized lesson plans grounded in an activity-oriented method, which emphasized traditional hands-on and interactive learning strategies. The instructional materials utilized in the study included:

- **Lesson Plans Based on Virtual Simulation based Instruction**
- **Lesson Plans Based on Activity Oriented Method of Instruction**

CONDUCT OF THE EXPERIMENT

Virtual Simulation based Instruction was implemented for the experimental group based on the unit "ORGANIC CHEMISTRY - SOME BASIC PRINCIPLES AND TECHNIQUES" from their Chemistry Textbook. The experimental intervention lasted for approximately 20 instructional days. Following the completion of the instruction sessions, the Test on Achievement in Chemistry was administered to both the Experimental and Control Groups as a Post-test. The scores obtained from the Pre-tests and Post-tests were subsequently analyzed using appropriate statistical techniques.

RESULTS AND DISCUSSIONS

1. Comparison of Pre-test Scores of Students in Experimental and Control Groups

The maximum scores of the test is 25. The arithmetic Mean of the scores obtained by the Experimental Group is 3.60 and that of the Control group is 3.38. The difference between them is 0.22. This indicates that the students in the Experimental and Control Groups does not differ significantly in their Pre-test scores.

The Median of the Experimental Group is 4 and Control Group is 3. This also indicates that the two groups do not differ significantly in their Post-test scores.

The low value of the Quartile deviation and Standard deviation for the both group that the scores do not differ very much from the average. The Skewness obtained for the scores of Pre-test for the experimental scores is 0.0424 and that of the control group is 0.187. The positive value of Skewness indicates that the students who scores low marks are more than those who scores high marks are more than those who scored low marks in the group.

2. Significance of difference between the Post-test, Pre-test means of the two groups.

The significance of the difference between the Pre-test Mean of the two groups was found by calculating Critical Ratio (CR). The data and the results are given in Table.

Comparison of the difference between the mean of the Pre-test scores of the Experimental and Control Groups

	Group	N	Mean	SD	t	P
Pre-test	Experimental Group	50	3.60	1.34	0.808	0.421

Group	N	Mean	SD	t	P
Control Group	50	3.38	1.38		

Since the table value is 1.984 at 0.05 level and 2.626 at 0.01 level, the obtained critical ratio value is lesser than the table value. H_0 is not significant. From this it is clear that the students of the two groups do not differ significantly in their pre-test scoring.

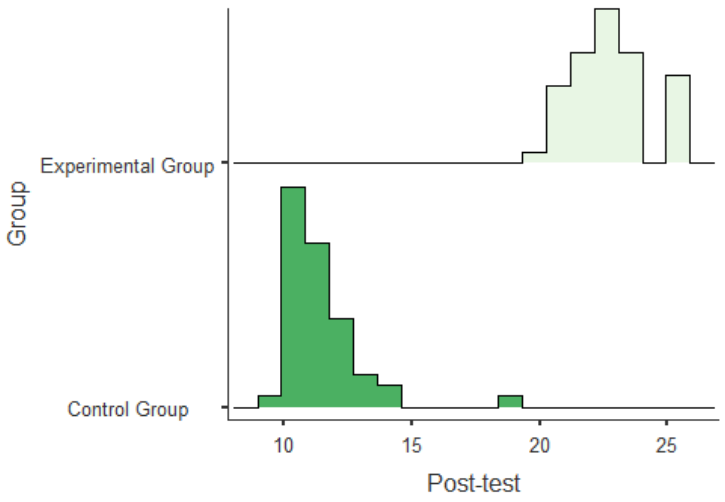
3. Performance of Students In Experimental And Control Groups After Experiment

A Post-test was administered to the Experimental Group. The Post-test scores obtained by the pupils in the group were condensed in to a Table and then calculated the Arithmetic Mean, Median, Mode, Standard Deviation, Quartile Deviation, Skewness and Kurtosis in order to get a clear picture of the performance of the group.

The total mark of the test is 25. The frequency distribution of the post scores of the Experimental Group is normal because the Mean (23), Median (23) and Mode (23) have equal value. It indicates that the performance of the group is good. The Skewness is -0.119 therefore the distribution is negatively skewed. So we can infer that the students who scored high marks were comparatively more in number than those who scored low marks in the group. The curve is leptokurtic, since the value of Kurtosis -0.817 which is less than 0.263.

The total mark of the test is 25. The frequency distribution of the post scores of the Control group is approximately normal because the Mean (11.1), Median (11) and Mode (10) have almost equal value. It indicates that the performance of the group is good. The Skewness is 2.73 therefore the distribution is positively skewed. So we can infer that the students who scored low mark is comparatively high in number than those who scored high marks in the group. The curve is platykurtic, since the value of Kurtosis 11.2 which is more than 0.263.

Graphical representation of Comparison of Pre-test scores of Test on Achievement in Chemistry of students in Experimental and Control Groups



4. Comparison of Post-test Scores of Students in Experimental and Control Groups

The maximum scores of the test is 25. The arithmetic Mean of the scores obtained by the Experimental

Group is 23.0 and that of the Control Group is 11.1. The difference between them is 11.9. This indicates that the students in the Experimental and Control Groups differ significantly in their Post-test scores.

The Median of the Experimental and Control Groups are 23 and 11 respectively. This indicates that the Experimental and Control Group achieved scores in the Post-test when compared to that of the Pre-test.

The Skewness obtained for the scores of Post-test for the scores of Achievement Test in Chemistry for the Experimental Group is -0.119 and that of the Control group is 2.73. The negative value of Skewness indicates that the students who scored high marks are more than those who scored low marks in the group. The positive value of skewness indicates that the students who scores low marks are more than those who scores high marks are more than those who scored low marks in the group.

5. Significance of difference between the Post-test Means of the two groups

The significance of the difference between the Post-test mean of the two groups was found by calculating Critical Ratio (CR). The data and the results are given in Table.

Comparison of the difference between the mean of the Post-test scores of the Experimental and Control Groups

	Group	N	Mean	SD	t	P
Post-test	Experimental Group	50	23.0	1.35	40.1	< .001
	Control Group	50	11.1	1.60		

Since the table value is 2.626 at 0.01 level and 1.984 at 0.05 level, the obtained critical ratio 40.1 is significant at 0.01 level. It means that there is significant difference between the means of the Post-test scores on Achievement Test in Chemistry of students in Experimental and Control Groups. It is clear that after the experiment, the students in the two groups differ significantly in their achievement in Chemistry. Since the mean of the Post-test scores of Experimental Group is greater than that of the Control group, the students in the Experimental Group is superior to the students in the control group in their achievement in chemistry, So it can be tentatively concluded that Virtual Simulation based Instruction teaching strategy in the Teaching of Chemistry has a greater effect on the student's Academic Achievement than Activity Oriented Method.

6. Comparison of effectiveness of Virtual Simulation Based Instruction And Activity Oriented Method Of Instruction

In order to compare the effectiveness of Virtual Simulation based Instruction and present method, the Pre-test and Post-test scores of the Experimental and Control Groups for Achievement Test in Chemistry was subjected to the statistical technique of analysis of covariance and the results obtained were presented as follows:

The Pre-test and Post-test scores of the Experimental and Control Groups for Achievement Test in Chemistry was subjected to Statistical Technique of Analysis of Covariance to determine the effectiveness of Virtual Simulation based Instruction over the Activity Oriented Method in Achievement.

The summary of analysis of variance of Pre-test and Post-test scores of students in Experimental and Control Group is given in the following Table.

Summary of ANCOVA of Pre-test and Post-test scores of Test on Achievement in Chemistry of students in the Experimental and Control Groups

	Group	N	Mean	SD	F	P
Pre test	Experimental Group	50	3.60	1.34	0.652	0.421
	Control Group	50	3.38	1.38		
Post test	Experimental Group	50	22.98	1.35	1608.4	<.001
	Control Group	50	11.12	1.60		

From Table F, for df 97 (Total), F{0.05}=3.94 and F{0.01}=6.90
The obtained F value was tested for significance. The table value of F-ratio for df 1/98 is 0.421 at 0 .05 level and 6.90 at 0.01 level the obtained F is highly significant at 0.05 level and 0.01 level (F=1608.4; P>0.05) That shows the post-test means differ significantly.
The summary of analysis of covariance of Pre-test and Post-test scores of students in Experimental and Control Group is given in Table.

Summary of ANCOVA of Pre–test Post–test scores of students in the Experimental and Control Groups for Test on Achievement in Chemistry

	Sum of Squares	df	Mean Square	F	P
Overall model	3479.62	2	1739.81	807.95	< .001
Pre-test	2.99	1	2.99	1.37	0.244
Group	3476.63	1	3476.63	1596.23	< .001
Residuals	211.27	97	2.18		

From Table F, for df 97 (Total), F{0.05}=3.94 and F{0.01}=6.90

The obtained F value was tested for significance. The table value of F-ratio for df 1/98 is 3.94 at 0 .05 level and 6.90 at 0.01 level. The obtained F is highly significant at 0.05 level and 0.01 level (F=0.244; P>0.05). That shows the post-test means differ significantly. It is clear from the significant F ratio that the two Post- test means of Experimental and Control Groups differ significantly, after they have been adjusted for difference in pre- test scores.
The adjusted mean of Post-test scores of students in the Experimental and Control Groups were computed. The difference between the adjusted means was tested for significance. The data for adjusted means of Post-test scores of student in Experimental and Control Groups are given in Table.

Data for adjusted means of Pre-test and Post- test scores of students in the Experimental and Control Group for Achievement test.

Group	N	Mean	SD	T	P

Data for adjusted means of Pre-test and Post- test scores of students in the Experimental and Control Group for Achievement test.

Group	N	Mean	SD	T	P
Experimental Group	50	23.0	1.35	40.1	< .001
Control Group	50	11.1	1.60		

Since the table value is 2.626 at 0.01 level and 1.984 at 0.05 level, the obtained critical ratio 40.1 is significant at 0.01 level. It means that there is difference between the adjusted means of the Post-test scores of students in Experimental and Control Group is greater than the minimum difference required. The significant difference between adjusted mean of the Post-test scores of Experimental Group is greater than that of Control Group, the students in the Experimental Group is superior to the students in the Control group in their achievement in Chemistry, since the adjusted means of the Experimental Group is significantly greater than that of pupils in the Control group. The Experimental Group is superior to the Control Group on Achievement in Chemistry. Therefore it may be concluded that Virtual Simulation based Instruction is much more effective than the Activity Oriented Method of Instruction at Higher Secondary School Level.

TENABILITY OF THE HYPOTHESIS

The hypotheses formulated for the study were tested for tenability in relation to the finding.

The hypothesis formulated was Virtual Simulation based Instruction is more effective than the Activity Oriented Method of Instruction on Achievement in Chemistry at Higher Secondary School Level.

This hypotheses is fully substantiated, since the t value calculated is significant at 0.01 level ($t=40.1$; $p<0.01$).

This hypothesis is accepted for the objective since the calculated value of t is significant at 0.01 level.

EDUCATIONAL IMPLICATIONS

The educational implications of virtual simulation in chemistry are profound and multifaceted. Virtual simulations serve as a powerful tool to enhance the teaching and learning experience in chemistry by enabling students to grasp complex concepts, develop scientific skills, and foster a positive attitude towards the subject.

- I**mproved Learning Outcomes**: Virtual labs have been shown to boost student achievement, self-efficacy, and overall learning outcomes. They provide an interactive and engaging environment for students to explore chemical concepts and conduct experiments safely.
- **Safety and Accessibility**: Virtual simulations eliminate the risks associated with handling hazardous chemicals in physical labs, making them a safer alternative. They also ensure inclusivity by offering access to laboratory experiences for students who may lack resources or physical access to traditional labs.

- **Flexibility and Cost Efficiency**: These simulations reduce economic and time costs, allowing students to experiment and learn at their own pace. They are environmentally friendly and adaptable to various learning environments.
- **Enhanced Conceptual Understanding**: Virtual labs provide opportunities for students to visualize and interact with complex chemical processes, offering clearer perspectives on challenging topics.
- **Instant Feedback and Engagement**: Students receive immediate feedback on their experiments, which helps in reinforcing learning and maintaining engagement.
- **Pedagogical Objectives**: Virtual simulations align well with curriculum goals, offering structured learning experiences that promote critical thinking and scientific competencies.

Virtual simulations in chemistry education not only improve academic performance but also cultivate interest and confidence in scientific exploration. They represent a shift towards modern, technology-driven education, preparing students for future scientific endeavors in a digitally integrated world.

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