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6. Effect of Dynamic visualizations integrated with interactivity on Spatial ability of learners

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Abstract

The ability of an individual to perceive and visualize mental transformations by rotating objects is Spatial ability of an individual. Spatial ability is an essential requirement for Learner engagement in the subject chemistry. The investigator intended to study the Effect of Instructional Strategy on Spatial Ability of undergraduate students by taking their Pre-Spatial Ability as covariate. The experimental study involved 342 Undergraduate students of Jabalpur. Participants of Experimental group (=185) were taught using Interactive Instruction (I.I) integrated with Dynamic visualizations (D.V) and participants of control group (=157) were taught by direct instruction. Spatial ability was measured by spatial ability test of DBDA Revised (David Battery of Differential Abilities) and the data was analyzed by two way Analysis of Covariance (ANCOVA). I.I integrated with D.V was found to be significantly superior to Direct Instruction in terms of spatial ability of learners when Pre-Spatial ability was taken as covariate. Thus use of appropriate instructional strategies like aforementioned is not only important for upgrading the spatial ability of learners but it will also facilitate better chemistry learning and would help in generating competent individuals; with better visual spatial skills.

Keywords: Interactive instruction, Chemistry, Spatial Ability, Dynamic visualizations, Undergraduate learners

Introduction

Starting college, particularly in India with its huge student diversity, can present a significant adjustment problem for many. This transition is often marked by a notable uptick in academic demands, especially in undergraduate science programs. In subjects like chemistry, students encounter a plethora of abstract concepts in both theory and practical classes, which can be

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quite challenging to grasp initially. Learners at both senior secondary level as well as college level frequently find it complex to understand the abstract concepts of chemistry. This specifically occurs in concepts involving mental manipulation of molecules. Karacop & Doymus (2013) suggest that the confusion in understanding chemistry mainly results from the incapability to comprehend the relationship between macroscopic, microscopic and sub-microscopic levels of representations. Understanding chemical bonding demands a thorough comprehension, as it entails constructing mental models that delve into the microscopic realm. As clearly indicated by BARKE & ENGIDA (2001) to learn chemistry effectively, a substantial level of spatial ability amongst learners is needed. Spatial ability is the ability of an individual to perceive and rotate objects mentally in two or three dimensional space. Spatial ability develops amongst the adolescent children to a level that they are able to analyse the structures of tetrahedral or octahedral molecules in the three dimensional space (BARKE & ENGIDA, 2001).

Dynamic visualizations like videos, animations and simulations have been widely used as instructional materials to help the learners visualize complex natural processes. Such visualisations are technology enabled and thereby help in visualizing not only macroscopic processes like that of solar system but also those microscopic phenomena’s which otherwise cannot be seen through naked eyes like atom, molecules, sub-atomic particles (electron, proton, neutron) and various forces that exist between molecules (Levy Dalit, 2013). Paul & Ayishabi (2016) suggested that spatial ability can be improved through visual media and so more and more visual programmes should be developed by experts and incorporated in teaching science. Kline & Catrambone (2012) suggested that learners with lower spatial ability would require other forms of assistance like animated instructions for mental model generation. Abanikannda M.O., (2016) and Dori Yehudit J. ,Sasson Irit, (2008) suggested the use of more computer based instructional packages for teaching chemistry in schools since it improved the achievement of learners specially the low academic level pupils.

Many studies have suggested that the use of appropriate instructional strategies is important for proper understanding of the concept by the learners. Activity based learning is student-centric and allows the learners to learn at their own pace. Martin Christopher B., Vandehoef Crissie and Cook Allison (2015) have used theoretical molecular modelling calculations in

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combination with Lewis dot structure and VSEPR theory to make students investigate the molecular geometries. The hands-on activity enabled the students to learn Lewis dot and VSEPR geometries in a concrete manner. This suggests that hands on activity along with interaction should be incorporated in instructional strategy. Wu, Krajcik and Soloway (2001) suggested that computerized models can serve as vehicle for students to generate mental images and showed that students who were engaged in discussion actively were able to build a link between the visual representations and the actual concept; thereby deepening their understanding. On the contrary Reiber Lloyd P. (1990) concluded that animated presentations can promote learning only under certain conditions. Multimedia instructional design should be such that the undesirable cognitive load is minimized (Cheon et al., 2014). For this the various principles of multimedia learning as proposed by Mayer must be kept in mind. According to Michael Joel (2006) "active learning doesn't just happen; it occurs in the classroom when the teacher creates a learning environment that makes it more likely to occur". He has also clarified that in order to get desirable learning outcomes the instructional techniques need to be properly planned as well as executed. Many studies have proved that interactive learning generates better learning outcomes.

Findings from several studies do highlight the importance of spatial ability; but it remains ambiguous how spatial ability maybe related to instruction. Thus the question arose in the mind of the researcher that can spatial ability of learners be improved if they are taught with dynamic visualizations integrated with interactivity? This study intended to find out the answer to this question by examining the effect of dynamic visualizations integrated with interactivity on spatial ability of UG learners (age 17-20years) while they were taught the topic of chemical bonding.

Need and significance of the study

As mentioned earlier; it is important to note that learners frequently find it complex to understand the abstract concepts of chemistry. They primarily face trouble in the topics which involve rotation of molecules in space i.e those involving spatial ability of the learners. One of the biggest evidence of this is that CBSE was forced to remove the chapter of stereochemistry from the senior secondary syllabus; which was earlier a part of the curriculum few years back. Students often face difficulty in concepts involving spatial visualization and thinking (Copolo & Hounshell, 1995). The studies mentioned above reveal that Spatial Ability can be improved through visualizations like animations and can address the gender gap that exists in spatial reasoning skills by providing hands-on experience to all the learners. Animations may increase conceptual understanding and achievement by prompting the formation of dynamic mental models of the phenomena. Students who were engaged in discussion actively were able to build a link between the visual representations and the actual concept. However animated presentations can promote learning only under certain conditions. The teacher must keep into consideration the previous knowledge of the learners and could overcome the shortcomings of animations using interactivity. Thus there is a need for intervention that incorporates the use of dynamic visualizations with interactivity.

Thus to assist the learners in getting a deeper understanding of such abstract concepts in chemistry, dynamic visualizations are often used as instructional tools. There were very few studies that incorporated the integration of visualizations with interactive active learning instructional strategies in instructor mediated classroom settings especially for the age group 17-20 years in India. In the knowledge of the researcher; there were hardly any studies related to effect of dynamic visualizations (segmented or non-segmented) integrated with interactivity on spatial abilities of learners in India. Undoubtedly there is an urgent need of intervention in the implementation of instructional strategies with respect to spatial abilities for the students in India. One such intervention was offered by this study; which focussed on determining the effectiveness of interactive instructional strategy integrated with dynamic visualizations on the spatial ability of learners at the undergraduate level in India.

The strategies used by a teacher for daily transactions between student and teacher through multiple instructional techniques, materials, tools and monitoring; that allows the learners to organize the information in a better manner were considered as Instructional strategies.

The two levels of instructional strategies considered in this study were direct instruction and Interactive instruction integrated with dynamic visualization. The two levels of Instructional strategy considered in this study are operationally defined as follows:

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a) Direct Instruction

The Direct instruction strategy includes the use of instructional methods like lecturing and didactic questioning and is primarily teacher centric in nature.

b) Interactive Instruction integrated with dynamic visualizations

The student centered interactive active learning instructional strategy using Visualization tools such as Videos, Animations, Simulations and Three-Dimensional videos which are interactive and go beyond the static forms are defined as Interactive Instruction integrated with dynamic visualizations.

Spatial Ability: In this study spatial ability was operationally defined as in the Revised Manual of David's Battery of Differential abilities:"Spatial ability is concerned with perceiving spatial patterns accurately and following the orientation of figures when their position in a plane or space is altered."

Objective

To study the effect of Instructional Strategy of teaching chemistry on Spatial Ability of undergraduate students of Jabalpur by taking their Pre-Spatial Ability as covariate.

Hypothesis

H_0: There is no significant effect of Instructional Strategy on Spatial Ability of undergraduate students by taking their Pre-Spatial Ability as covariate.

Method

Experimental method was used by the researcher for this study. The researcher used Non-Equivalent Pre-test Post-test Control Group Design belonging to Quasi Experimental Design.

Population: Those UG participants of Autonomous A-accredited colleges were selected who studied chemistry as a one of the subjects.

Sample size: Stratified random sampling was used. The total sample size was 342 UG students of Jabalpur; where Experimental group had 185 participants (107 females and 78 males) and Control Group had 157 participants (75females and82 males).

Tools: To measure the spatial ability of the UG students, a standardised Spatial ability test of the DBDA Revised (David Battery of Differential Abilities) by Dr Sanjay Vohra was used. This tool was used because the revised version of DBDA; revised by Dr Sanjay Vohra was done on the Indian population. The test can be both individual as well as group administered. The standardisation done by Dr Vohra across twelve locations in India; involved school participants, college participants and adults. The reliability coefficient of the spatial ability (SA) test found using KR-20 was 0.92; split half reliability of 0.95 and test-retest reliability of 0.85; points out that the SA test of DBDA revised is highly reliable. The correlation values of the SA test were also found with intelligence test and academic achievements.

Procedure

The researcher selected Non-equivalent pre-test post-test Control group design since the random assignment was not possible. The UG students of Autonomous A-accredited colleges (having chemistry as one of the subjects) of Jabalpur district was considered as the population. The two colleges randomly selected were Government Model Science College and St. Aloysius College. Thus N= 280+925= 1205. A sample size of 400 was selected randomly. However there were missing cases, non-availability of post-test and pre-test scores of some of the participants. Thus at the end of data collection, the complete data of 342 participants was available i.e the actual sample size whose data was analysed was 342.

The sample selected was divided into experimental and control group. Since the study involved Non-Equivalent Group design, so the classes were taken intact and were randomly assigned as Experimental and Control groups. The data was collected from two colleges namely- Government Model Science College, Jabalpur, M.P and St. Aloysius College, Jabalpur, M.P. The topic chosen to be taught was Chemical bonding and molecular structure. Before the treatment was given, a pre-test of spatial ability was administered in both the groups. The Control group was taught topic by direct instruction and the Experimental group was taught by Interactive Instruction integrated with dynamic visualization. Both the groups were taught for duration of one month. The lessons involved active learning strategies such as Peer instruction(PI), Think Pair Share (TPS) and Predict Observe Explain (POE) along with integration of dynamic visualizations such as animations, simulations and videos as a part of treatment to experimental group. The experimental group was taught with interactive instructional methods integrated with simulations and interactive videos as aids. Various Educational resources like videos, animations, simulations and three-dimensional videos were used. As a part of treatment, the students of experimental group were taught with one of the animations prepared by the Central Institute of Educational Technology (CIET), NCERT. The animation on “Chemical bonding & molecular structure” (MM-12) circulated by CIET, NCERT and prepared by Dr Kamlesh Mittal, Department of Computer Education and Technological aids was utilized for the treatment. This video was integrated with interactive discussions and sessions in the lesson plans prepared by the researcher.

The students of experimental group were also taken to the State Institute of Science Education(SISE), Jabalpur; where few lessons were delivered. The three dimensional videos and simulations (on VSEPR Theory, Hybridisation, shapes of covalent molecules, MO diagram for homonuclear and heteronuclear molecules) available in the institute served as the dynamic visualizations which were integrated with interactive teaching by the researcher. The three dimensional videos were also used in lesson plans in such a manner that allowed ample prompting by the teacher and interaction by the learners. After the treatment was completed a post-test of spatial ability was administered in both the groups.

Result

The data was analyzed by Two way Analysis of Covariance (ANCOVA) in SPSS. The tables so obtained are shown below in Table 1 and Table 2 . From Table 1 it can be seen that the adjusted F-value is 21.640 which is significant at 0.01 level with df=(1,337). So there was a significant effect of Instructional strategy on spatial ability of UG students when Pre-spatial ability was taken as covariate. Additionally from Table 2, it can be observed that the adjusted mean score of Spatial ability of UG students taught through I.I integrated with D.V (=57.107) was significantly higher than those taught through Direct instruction(=53.127), when Pre-spatial ability was taken as covariate. Thus I.I integrated with D.V (experimental group) was found to be significantly better than Direct Instruction (control group) in terms of mean scores of spatial ability; when Pre-Spatial ability was taken as covariate.

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Table 1: Scores of Spatial ability of UG students with Pre-Spatial ability as covariate

Source	Df	Type III Sum of Squares	Mean Square	F	Partial ή^2
PRE-S.A	1	21602.177	21602.177	359.062**	0.516
INSTRUCTIONAL STRATEGY	1	1301.912	1301.912	21.640**	0.060
Error	337				
Total	342	1087581.000			

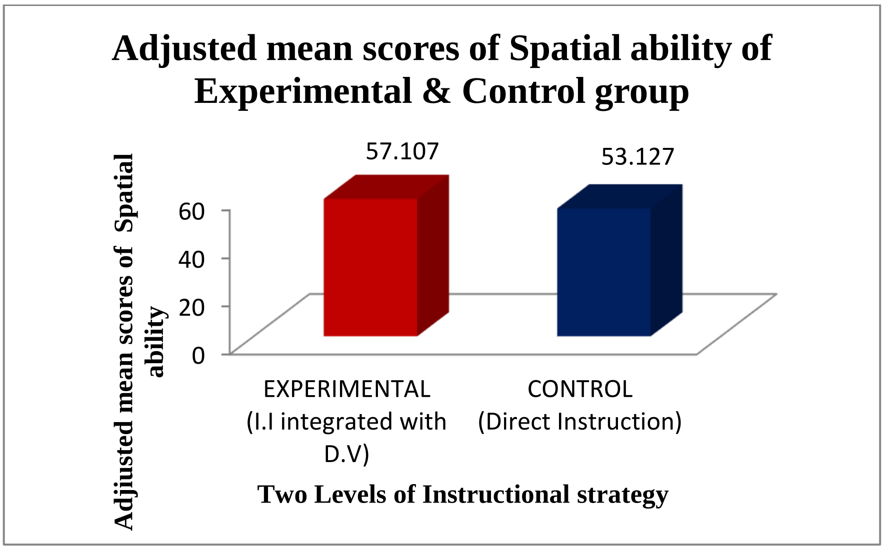
*significant at 0.01 level

Table 2: Adjusted mean scores of spatial ability of Experimental & control group, Male & female UG students

	Adjusted mean scores
EXPERIMENTAL	57.107[a]
CONTROL	53.127[a]

Graph 1 clearly shows that the adjusted mean scores of spatial ability of the students in experimental group was much higher than the adjusted mean scores of spatial ability of the students in control group.

Graph 1: Graphical representation of adjusted mean scores of spatial ability of Experimental and Control group



Discussion

Thus I.I integrated with D.V (experimental group) was found to be significantly better than Direct Instruction (control group) in terms of mean scores of spatial ability; when Pre-Spatial ability was taken as covariate. The studies conducted by Cheon et al. (2014) and Fong (2013) have highlighted that segmentation of visualizations along with usage of active pauses by involving the learners in active learning activities is essential. Since structural differences between molecules may be difficult to visualize (Copolo & Hounshell, 1995), dynamic visualizations prove to be powerful instructional aides to enhance student's understanding. Hegarty (nd) found that, in learning with dynamic visualizations (in contrast to non-dynamic visualizations), spatial ability might play the role of an enhancer. Kriz Sarah & Hegarty Mary (2007) and Tversky B, Morrison, J.B. & Betrancourt,M. (2002) also suggested that learning from animations is not as easy as it seems; more stress should be laid on how the previous knowledge of the learners is used to interpret and understand these animations and that the limitations of animations could be overcome using interactivity. Thus the results obtained are in sync with the previous studies that usage of dynamic visualizations is beneficial for the learners.

The investigator realized during the data collection that the students of experimental group were more interactive, curious and attentive in comparison to the students of the control group. Since the experimental group was more participative due to the usage of dynamic visualizations along with interactive instruction, so this could possibly be the reason for improvement in the spatial ability of the learners of experimental group.

Conclusion

Spatial ability of a learner has wide range of Educational implications in terms of identifying exceptionally gifted children, in making decisions regarding learners showing poor academic performance and finally providing necessary guidance and counselling. To develop the spatial ability of learners, there needs to be an intervention in terms of usage of interactive instructional strategies integrated with dynamic visualizations which would promote the learners to visualize and comprehend the complex concepts of chemistry easily; leading to better learning outcomes. An efficient visual learner will ultimately turn out to be more capable future chemist; making worthy contributions in the field of chemistry.

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