Journal of Interdisciplinary and Multidisciplinary Research (JIMR)
E-ISSN:1936-6264| Impact Factor: 8.886| UGC CARE II
Vol. 19 Issue 03, March- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary, monthly, and fully refereed journal.)

ACHIEVING 'TECHNOLOGY DRIVEN INTERACTIVE UG CHEMISTRY CLASSROOMS' ALIGNED WITH NEP 2020 FRAMEWORK IN JABALPUR

Dr. Aparajita Sengupta, Assistant Professor, Department of Science Education, SAIT Education, Jabalpur, M.P.

ABSRACT

The National Education Policy 2020 has highlighted the importance of technological interventions in improving the teaching learning and evaluation process. There is a need to streamline the technology intervention in TLP in higher education in India. The educators and teachers need to upgrade themselves professionally by adopting and creating new innovative, interactive and technology integrated teaching methods in classrooms. The current study is an attempt to understand how the I.I.I.D.V (interactive instructions integrated with dynamic visualizations) model could be used by teachers in improving the chemistry achievement of the Undergraduate learners in Jabalpur district. The researcher found that I.I.I.D.V plays a role in lessening the differences across students of varied intelligence with respect to their chemistry achievement with a moderate effect size. The use of interactivity integrated with dynamic visualizations not only leads to better and concrete chemistry learning but also improves their visual spatial skills resulting in overall holistic skill development, which is one of the primary goal of NEP 2020. The outcomes of the present study is in sync with the broader objectives of the policy that aims to attain technologically driven interactive classrooms resulting in overall holistically developed learners.

Keywords: Interactivity, Dynamic Visualizations, NEP 2020

INTRODUCTION

The National Education Policy 2020 document aims to recognize, identify and foster the unique capabilities of each learner. According to NEP, 2020 document, "main thrust of this policy regarding higher education is to end the fragmentation of higher education by transforming higher education institutions into large multidisciplinary universities, colleges, and HEI clusters/Knowledge Hubs" (NEP 2020, MHRD, p.35). It has highlighted that just like the universities of ancient India (Nalanda, Takshila, Vikramshila and Vallabhi) were progressive and had been able to attract students from all over the world due to their multidisciplinary nature, similarly today's need of the hour is to make the universities and colleges multidisciplinary both in teaching as well as research.

Apart from emphasis on conceptual understanding, critical thinking, creativity, life skills, there is a notable emphasis by the policy on extensive use of technology in teaching and learning process. There would be use of technology in teaching learning and assessment to improve access and equity, and increasing access for disadvantaged groups. There would be appropriate use of technology in administration and management of Higher education. This policy discusses of creation of content, setting up of digital repository and its distribution for access to all. The digital repository would include learning games, simulations and content based on augmented reality and virtual reality would be developed. The newer concepts like gamification in education, fun based learning apps in various languages, and use of Blended models of learning for different subjects would be introduced and developed.

The NEP 2020 stresses on creating a holistic environment where the learners could develop their knowledge as well as 21st century life skills and teachers could develop and expand their prevailing skill sets. Creating technology driven classrooms for teaching learning and evaluation process to create enriching environment has become imperative now. Thus the educators need to change and improve upon their Instructional strategies to attain this.

Chemistry learning at the Undergraduate level requires exhaustive visualization capabilities and conceptual understanding. When we talk of critical concepts in chemistry taught at masters level (in India) like group theory; it makes use of exhaustive visualisation capabilities of an individual since it involves not only rotation along an axis; but reflection along a plane. Most of the learners face difficulty in understanding the concept of group theory; specifically in identifying the point group of molecules. Not only the learners, but even many instructors are not clear about the concept of group theory and have many misconceptions about the same. Apart from complex concepts of stereochemistry and group theory; one of the most basic concepts in chemistry which involves the visual spatial ability of the learners is atomic structure and chemical bonding.

Any kind of visualization engages a learner more and spurs brainstorming. It is primarily useful for those concepts which are difficult to visualize. As early in the era of 90's there was a technological gap between the learner's school and outside school environment (Habraken, 1996). The extent of visual exposure then and now is different. The visual exposure through video games, play station, smart phones, television, internet, computers, tablets, i-pads etc all play a very influential role in building up learner's thinking and perception. The interactive nature of such gadgets and media makes them more attractive; thereby bringing the learners at ease by making them think visually. As early in 1996, Habraken had bought forth the importance of developing visualization skills by chemists using technology. Visualization may be either static or dynamic in nature. Static visualization includes figures, graphs, images etc. Dynamic visualization includes animations, simulations, video.

Animations which are dynamic in nature generally are superior to the static graphics in terms of buildup of mental models by the learners (Hoffler& Leutner,2007; Wouters, Paas, & van Merriënboer, 2008 as cited in Cheon et al., 2014). Animations unlike static images provide the learners the opportunity to observe the same concept in motion along with path followed (Karacop & Doymus, 2013).

It may be noted that animations are not always better than static graphics since they may cause cognitive overload of the learners (Cheon et al., 2014). The information displayed in multifaceted and intricate animations is for a short span of time; thereby making it difficult for the learners to process each and every information of the animation (Hegarty et al., 2003). The dynamic nature of visualizations may also be a potential disadvantage as well. It may confuse the learners and may delay their learning. Bodemer et al., (2005) have pointed out that dynamic visualizations may put an additional burden on the cognitive load thereby preventing the self-learning of the learners. When such flowing information is continuously bombarded on the learners; in form of dynamic visualisations, it also overburdens the cognitive abilities of the learners. (Lowe,1999 as cited in Bodemer et al., 2005).They have suggested that in order to initiate discovery learning along with interactive dynamic visualisations, such interactive learning environment must be well structured. Bodemer et al., (2005) found that when learners are exposed to dynamic and interactive visualizations, they are not always able to grasp or understand the concept displayed in a logical manner.

The Paivio's dual-coding theory and the Cognitive theory of multimedia learning explain the effectiveness and usefulness of animations.Cognitive load theory clearly suggests that the instructional strategy should be such that the intrinsic load should be coped up with; extraneous load should be minimised and the germane load should be enhanced (Khalil & Elkhider, 2016). Another point that this theory highlights is that the limitation of the working memory must be kept in mind while instructional design; otherwise it will unnecessarily increase the cognitive load. For example, while using animations to explain the types of atomic orbitals; it is preferable to speak the text rather than showing the text along with the visuals in the animations. Both these theories aim to help instructional designers to make use of such instructional strategies that help in reducing extraneous cognitive load and help learners to manage the new information that is presented to them.

In the direction of developing a 'Blended model of learning for different subjects' as per the NEP 2020, the researcher thought of developing a model with an Instructional strategy that integrated technology as well as interactivity specifically for the subject chemistry at the Undergraduate level. The student centered interactive active learning instructional strategy using Visualization tools such as Videos, Animations, Simulations and Three-Dimensional videos which were interactive and went beyond the static forms were defined as Interactive Instruction integrated with dynamic visualizations (I.I.I.D.V.) by the Researcher.

Many studies have suggested that the use of appropriate instructional strategies is important for proper understanding of the concept by the learners. Instructional strategy is the plan or approach by which the instructor achieves the specified learning objectives. Instructional strategy is primarily either teacher centric or student centric. Instructional strategies are such which create a positive learning environment in classroom, allowing learners to gain active learning experiences in all three domains (AkdenizCelal, 2016). Active learning is the approach that is used to keep the students engaged with the learning content by various means such as participation in question answers, discussion, writing, solving problems and speaking out; such that the students are able to think actively, reflect and express themselves (Kavya Alse and Anurag Deep, 2016). However it is not necessary that active learning classrooms may always be successful since it depends on certain parameters like time constraint, type of topic on which activities or discussions are held and type of active learning strategy used.

Three active learning strategies namely Peer Instruction (PI), Think Pair Share (TPS) and Predict Observe Explain (POE) were used by the researcher as the interactive components of the I.I.I.D.V.Peer Instruction or PI as it is commonly known was proposed by Eric Mazur; a physicist at Harvard University. PI is an active learning strategy to make students participate in series of activities like answering a question in form of voting, followed peer discussion, then again voting after discussion and finally clarification of doubts by teacher. Think pair share which was proposed by Frank Lyman of University of Maryland; is a method best suited for students of higher classes. This active learning strategy involves teacher posing a master question, then the students undergo the 'think' phase, they are paired up with other students, followed by the 'share' phase where they discuss their answers and finally teacher provides them feedback and information regarding the concept. POE can be very well used with visualization tools. The students are shown a portion of the visualization, where they observe the visualization carefully. Thereafter they are asked to make predictions along with discussions for the question posed by the teacher. The teacher finally explains and corrects the conceptual understanding of learners by playing the visualization. The students are thus able to analyse and relate their own learning to the actual concept.

Different instructional strategies need to be used along with animations; so that it leads to better understanding since animations in isolation may be inadequate (Karacop & Doymus, 2013). In short we could formulate that animations along with interactive teaching may or may not effect the academic achievement of learners. So teaching with animations and interactive in nature of the lesson both have an important role to play. This is coherent with the Paivio's dual coding theory which clearly says that learning from animation is enhanced when clubbed with apt verbal cues.

NEED AND IMPORTANCE

One of the notable concerns in teaching learning process for the subject Chemistry in schools and colleges is inadequacy of relevant instructional materials and use of inefficient instructional strategies. Mayer, R.E. (1995) has indicated through his study that learners with higher spatial ability generally are likely to be able to make a mental integration of verbal and visual representations from multimedia visualizations; whereas learners with low spatial ability find it difficult to hold the images in memory thereby making it grueling for them to integrate visual and verbal representations. How does technology integrated with interactive instructional strategies (in sync with the NEP 2020 framework), impact the achievement in chemistry of the undergraduate students? Does other parameter like intelligence also effect the achievement in chemistry of learners? In order to search for answers to these questions, the researcher selected this topic for study.

There was a need, to better understand how instructional strategy of teaching chemistry could have an effect on achievement in chemistry of learners because there are contradictory results in terms of achievement in chemistry when D.V or various external representations were used for teaching learning process. Use of such visualizations or representations may not necessarily improve learning but may also delay or slow down learning. In order to improve learning outcomes in chemistry especially at the UG level, there was a need that it is further studied. Use of I.S which is interactive along with D.V is important to be used to understand its effect on learning chemistry.

OBJECTIVE

Objective was: To study the effect of Instructional Strategy, Intelligence and their interaction on Achievement in Chemistry of undergraduate students by taking Pre - Achievement in Chemistry as covariate.

HYPOTHESIS

Null hypothesis was: There is no significant effect of Instructional Strategy, Intelligence and their interaction on Achievement in Chemistry of undergraduate students by taking Pre - Achievement in Chemistry as covariate.

RESEARCH METHODOLOGY

Experimental method was used by the researcher for this study. The sample was selected from a population of Autonomous A-accredited colleges of Jabalpur. There were 342 participants selected through Random sampling method. The Experimental group had 185 participants and Control Group had 157 participants.

The student centered interactive active learning instructional strategy using Visualization tools such as Videos, Animations, Simulations and Three-Dimensional videos which were interactive and went beyond the static forms were defined as Interactive Instruction integrated with dynamic visualizations. (I.I.I.D.V)

The tools used were Standardized Achievement test of chemistry prepared and standardized by the researcher &Raven's Standard Progressive Matrices for Intelligence. Two way Analysis of covariance was used for data analysis.

RESEARCH PROCEDURE AND DATA COLLECTION PROCESS

The research procedure is summarised below in the figure 1.1 and figure 1.2 summarises the data collection process.

Figure 1.1: Research procedure

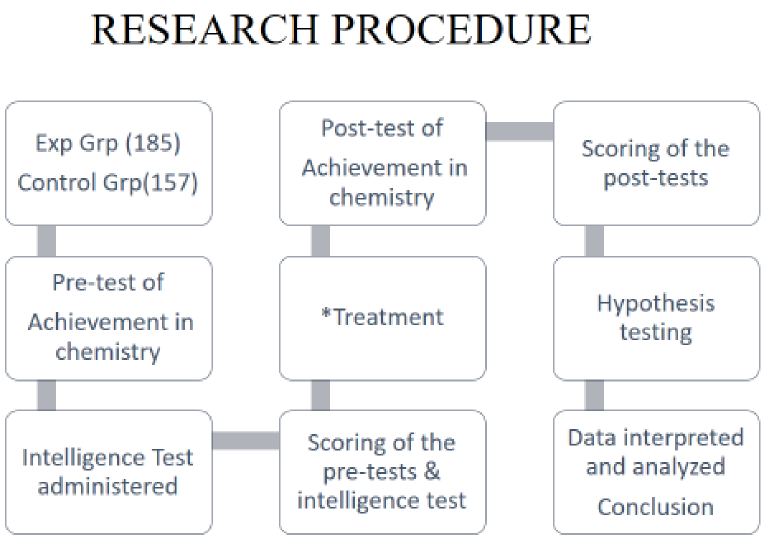
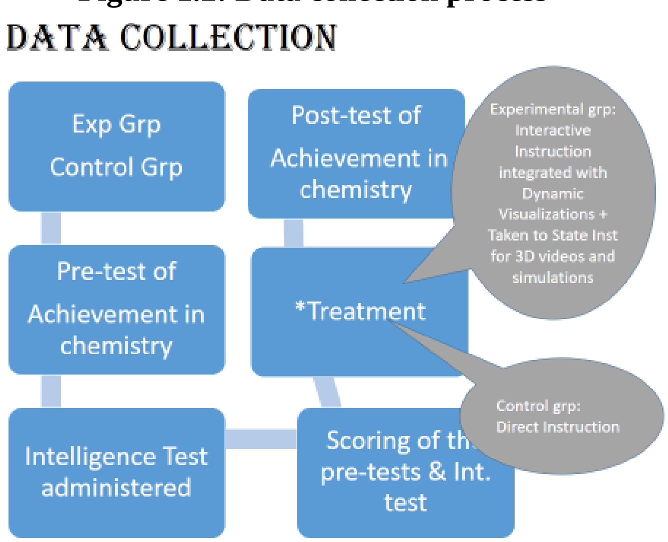


Figure 1.2: Data collection process



FINDINGS AND INTERPRETATIONS

The data were analysed with the help of 2 X 3 factorial design ANCOVA by taking Pre-Achievement in chemistry as covariate and the consolidated results are given in Table 1.1 .The findings are explained in the following paragraphs.

Table 1.1: Overall findings

Sr.No.	Sub-objective	Findings	Effect size
1.	Effect of Instructional Strategy on Achievement in chemistry of undergraduate students by taking their Pre- Achievement in chemistry as covariate	**Significant at 0.01 level** ($H_{0(4a)}$ Rejected)	For I.S ; partial $ή^2$ = 0.046 **Moderate effect size**
2.	Effect of Intelligence on Achievement in chemistry of undergraduate students by taking their Pre- Achievement in chemistry as covariate	**Significant at 0.01 level** ($H_{0(4b)}$ Rejected)	For Intelligence ; partial $ή^2$ = 0.054 **Moderate effect size**
3.	Effect of interaction between Instructional Strategy and Intelligence on Achievement in chemistry of undergraduate students by taking their Pre- Achievement in chemistry as covariate	**Significant at 0.05 level** ($H_{0(4c)}$ Rejected)	For I.S * Intelligence; partial $ή^2$ = 0.026 Small effect size

The covariate pre-achievement in chemistry, was significantly related to the achievement in chemistry of learners, F (1,335) = 186.016, p<0.01, partial $ή^2$ = 0.357**.** The partial eta squared value of pre-achievement in chemistry indicates the effect size, which is 0.357.It reflects that the pre-achievement in chemistry is a covariate creating smaller effect.

The descriptive statistics are given in Table 1.2 followed by Table 1.3 which gives the Summary of 2 X 3 Factorial design ANCOVA of Achievement in chemistry of UG students by taking Pre- Achievement in chemistry as covariate.

Table 1.2: Means, Adjusted means, Standard Deviations and Standard Error for achievement in chemistry for the four intervention groups

	Intervention Group					
	Experimental			Control		
Achievement in chemistry	Above average	Average	Below Average	Above average	Average	Below Averag e
M	13.155	11.012	9.429	11.906	10.519	8.074
(SD)	2.462	2.883	2.065	2.740	2.506	3.699
Madj	12.646	11.198	10.707	10.904	10.937	9.168
(SE)	0.242	0.235	0.593	0.310	0.251	0.429
N	84	87	14	53	77	27
	N(expt) =185			N(control) =157		

Table 1.3: Summary of 2 X 3 Factorial design ANCOVA of Achievement in chemistry of UG students by taking Pre- Achievement in chemistry as covariate.

Source	Df	Type III Sum of Squares	Mean Square	F	Partial ή2
PRE-ACHIEVEMENT	1	891.494	891.494	186.016**	0.357
INSTRUCTIONAL STRATEGY	1	76.564	76.564	15.976**	0.046
INTELLIGENCE	2	91.023	45.511	9.496**	0.054
INSTRUCTIONAL STRATEGY *INTELLIGENCE	2	42.414	21.207	4.425*	0.026
Error	335				
Total	342	46620.000			

** Significant at 0.01 level, *significant at 0.05 level

a) Effect of Instructional Strategy on Achievement in chemistry of undergraduate students by taking their Pre- Achievement in chemistry as covariate.

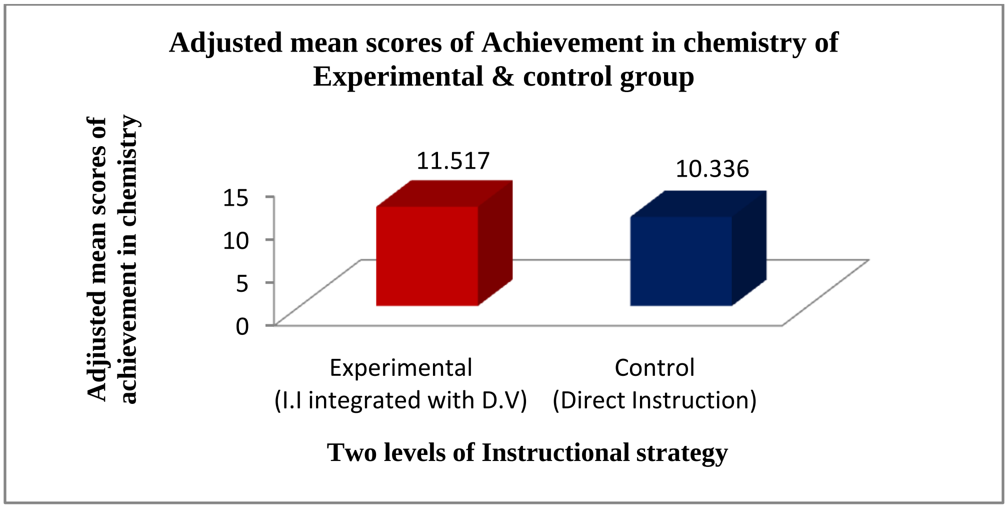
From table 1.3 it can be seen that the adjusted F-value for Instructional strategy was 15.976 which is significant at 0.01 level with df=(1,335). It reflects that the adjusted mean scores of achievement in chemistry of undergraduate students taught through I.I integrated with D.V and Direct instruction differ significantly when Pre-achievement in chemistry was taken as covariate.So there was a significant effect of Instructional strategy on achievement in chemistry of undergraduate students when Pre-achievement in chemistry was taken as covariate. Thus the sub null hypothesis "There is no significant effect of Instructional strategy on achievement in chemistry of undergraduate students by taking Pre-achievement in chemistry as covariate" was rejected. Significant results do not necessarily mean that the effect that is being measured has practical significance or is meaningful. The magnitude or extent to which this difference is significant or meaningful is determined by the effect size. As per table1.3, the effect size determined by $ή^2 = 0.046$ i.e. 4.6%; which shows that the effect size is almost moderate. It means 4.6% of variance in achievement in chemistry of learners is explained by the effect of Instructional strategy.

Table 1.4 gives the Adjusted mean scores of Achievement in chemistry of Experimental & control group. The adjusted mean score of the experimental group was higher than that of the control group. It may therefore be said that I.I integrated with D.V was found to be significantly superior to Direct Instruction in terms of achievement in chemistry when pre-achievement in chemistry was taken as covariate. The graphical representation of the same is shown in graph 1.1.

Table 1.4: **Adjusted mean scores of Achievement in chemistry of Experimental & control group**

Group	Adjusted mean
Experimental (I.I integrated with D.V)	11.517
Control (Direct Instruction)	10.336

Graph 1.1: Graphical representation of adjusted mean scores of Achievement in chemistry of Experimental & control group



b) Effect of Intelligence on Achievement in chemistry of undergraduate students by taking their Pre- Achievement in chemistry as covariate.

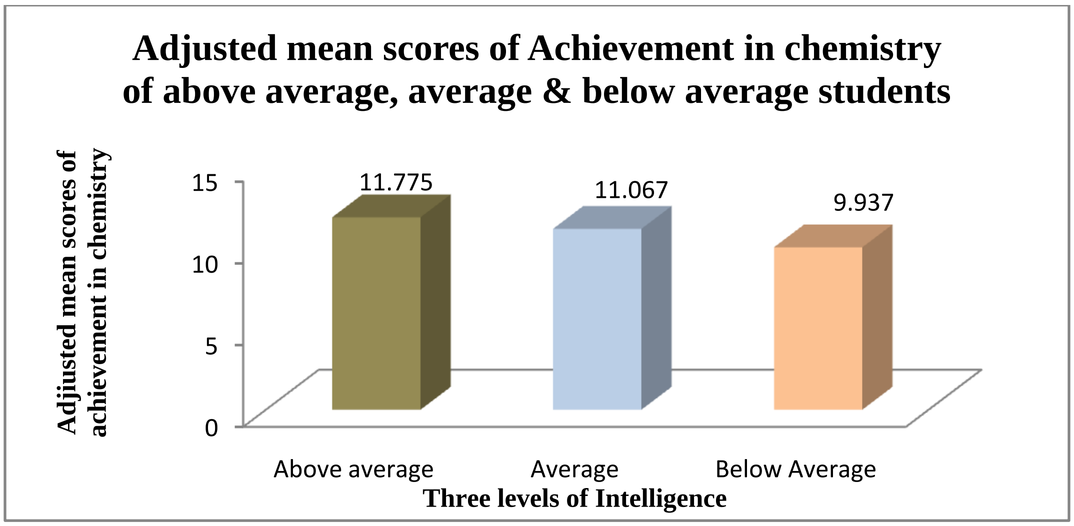
The adjusted F-value for Intelligence was 9.496 which is significant at 0.01 level with df= (2,335) (vide table 1.3). It shows that the adjusted mean scores of achievement in chemistry of above average, average and below average undergraduate students differs significantly when pre-achievement in chemistry was taken as covariate. So there was a significant effect of Intelligence on achievement in chemistry of undergraduate students when pre-achievement in chemistry was taken as covariate. Thus the sub null hypothesis b) was rejected. The effect size determined by $ή^2$ = 0.054 i.e. 5.4%; which shows that the effect size is moderate. It means 5.4% of variance in achievement in chemistry of learners is explained by the effect of Intelligence.

Table 1.5 gives the Adjusted mean scores of Achievement in chemistry of above average, average & below average students. The adjusted mean score of achievement in chemistry of above average undergraduate students was 11.775 which is significantly higher than that of average & below average undergraduate students whose adjusted mean scores of achievement in chemistry were 11.067 & 9.937 respectively; when pre-achievement in chemistry was taken as covariate. It may therefore be said that the achievement in chemistry of above average undergraduate students was found to be significantly superior to the achievement in chemistry of average & below average undergraduate students when pre-achievement in chemistry was taken as covariate. The graphical representation of the same is shown in graph 1.2.

Table 1.5(a): **Adjusted mean scores of Achievement in chemistry of above average, average & below average students**

Group	Adjusted mean score
Above average	11.775[a]
Average	11.067[a]
Below Average	9.937[a]

Graph 1.2: Graphical representation of adjusted mean scores of Achievement in chemistry of above average, average & below average students



On looking at the adjusted mean scores of achievement in chemistry of above average, average and below average learners; it seemed that there was a significant difference in the mean scores of the three intelligence groups. The Sidak-corrected post hoc pair-wise comparisons as shown in Table 4.4.3(b) confirmed that the adjusted mean scores of achievement in chemistry of all the three groups differed significantly. The means of above average and average students differ significantly (p=0.026), the means of the above average and below average students differ significantly (p=0.000) and the means of average and below average students differ significantly (p=0.016); all at 0.05 level of significance.

Table 1.5(b):Sidak corrected post hoc comparisons for the achievement in chemistry scores of above average, average and below average learners

		Mean difference	Std. Error	Sig.[a]
Above average	Average	.708*	.269	.026
	Below average	1.838*	.433	.000
Average	Above average	-.708*	.269	.026
	Below average	1.130*	.404	.016
Below average	Above average	-1.838*	.433	.000
	Average	-1.130*	.404	.016

* significant at 0.05 LOS; Sig.[a] adjustments for multiple comparisons: Sidak

c) Effect of interaction between Instructional Strategy and Intelligence on Achievement in chemistry of undergraduate students by taking their Pre- Achievement in chemistry as covariate.

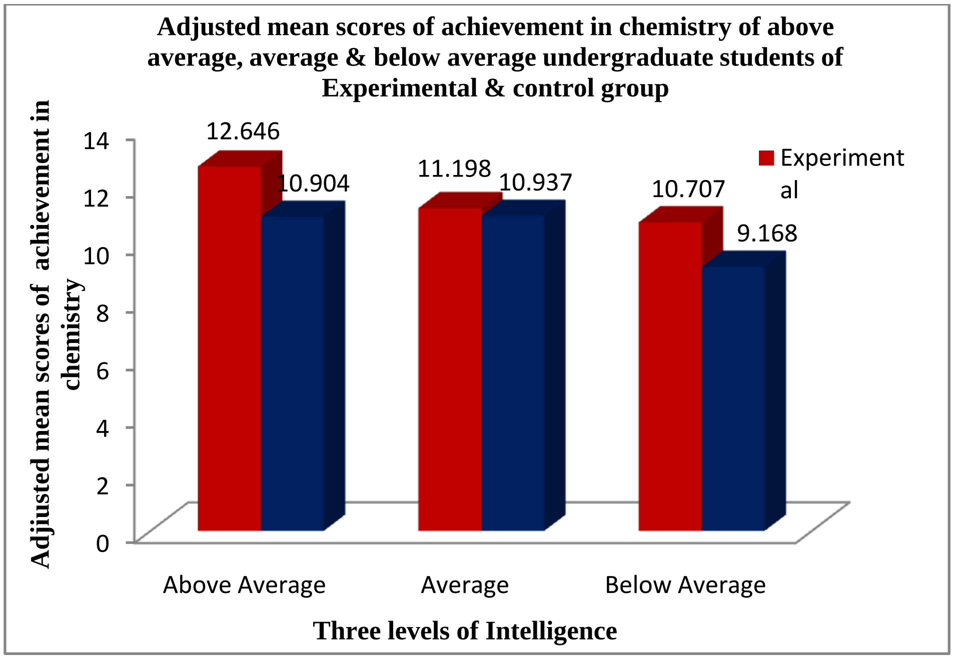
The adjusted F-value for interaction between Instructional strategy and Intelligence was 4.425 which is significant at 0.05 with df= (2,335) (vide table 1.3). It indicates that the adjusted mean scores of achievement in chemistry of above average, average & below average undergraduate students taught through I.I integrated with D.V and Direct instruction differ significantly when Pre- achievement in chemistry was taken as covariate. Thus sub null hypothesis c) was rejected. The effect size determined by $ή^2 = 0.026$ i.e. 2.6%; which shows that the effect size is small. It means 2.6% of variance in achievement in chemistry of learners is explained by the interaction effect of Instructional strategy and intelligence.

Table 1.6 indicates the adjusted mean scores of achievement in chemistry of UG students due to interaction between Instructional strategy and intelligence. Graph 1.3 shows that overall the adjusted mean scores of achievement in chemistry of students in the experimental group was higher than the adjusted mean scores of achievement in chemistry of students in the control group.

Table 1.6:Adjusted mean scores of achievement in chemistryof above average, average & below average undergraduate students of Experimental & control group (2X2 F.D)

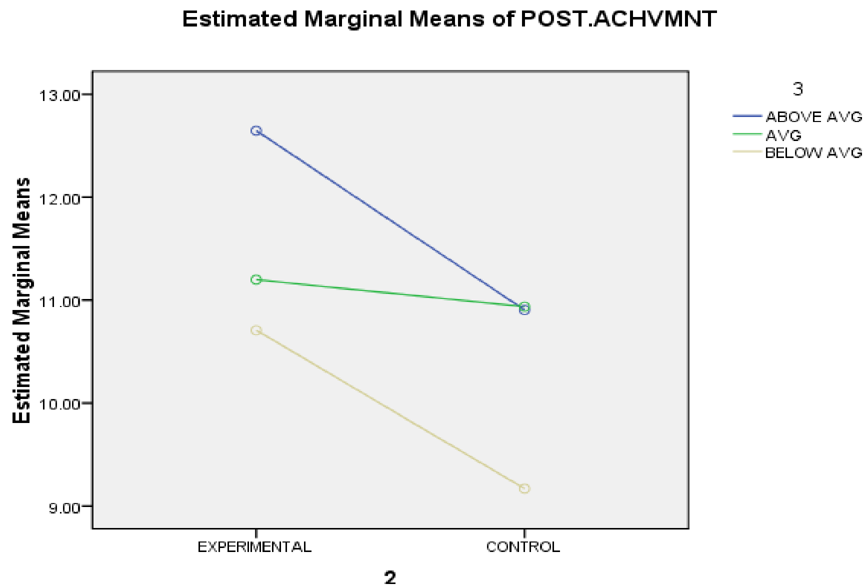
	Adjusted mean scores	
	Experimental	Control
Above Average	12.646[a]	10.904[a]
Average	11.198[a]	10.937[a]
Below Average	10.707[a]	9.168[a]

Graph 1.3: Graphical representation of adjusted mean scores of achievement in chemistry of above average, average & below average undergraduate students of Experimental & control group



Graph 1.4 is the graphical representation of the significant interaction between instructional strategy and intelligence; when pre-achievement in chemistry is taken as covariate.

Graph 1.4: Graphical representation of interaction between instructional strategy and intelligencewhen pre-achievement in chemistry is taken as covariate



DISCUSSION

The findings are in sync with the previous literature. Abanikannda M.O., (2016) and Williamson Vickie M., Abraham Michael R. (1995) showed that treatment with animations increased not only the performance and attention span but also the conceptual understanding and achievement of learners by prompting the formation of dynamic mental models of the phenomena. Similarly (Akaygun, 2016) showed that the students' mental model of atomic structure improved and became more precise on using dynamic visualisations. (Cheon et al., 2014), Ardac & Akaygun (2004) highlighted the importance of prompting and active pauses during use of segmented animated graphics. Similarly in this study also the researcher used active pauses and segmented the animations; and as a result the scores in achievement in chemistry of the experimental group taught by dynamic visualizations were moderately better than control group. At the end of the treatment in experimental group; the participants who were taught with Interactive instruction integrated with dynamic visualization were asked to fill a feedback form. They were asked to fill up the form based on their learning experiences during the treatment. More than 85% of the students thought that a) Use of animations, simulations and three dimensional videos helped them learn in a better manner. b) When the instructor used active pauses in between the dynamic visualizations, it helped them think clearly and clarified their doubts. c) Listening to other student's answers and classroom discussion further enhanced their understanding of concepts. d) This type of student- student interaction must be allowed in other subject's classes also.

EDUCATIONAL IMPLICATIONS

The current study has implications for the use appropriate instructional strategy by teachers. Such interactive learning activities integrated with the usage of dynamic visualizations not only endorses high-level thinking amongst learners; but it also promotes associative learning based on the visualisations observed in the classroom and the activities done. Thus teachers must try and use such interactive instructional strategies integrated with DV which not only enhance their achievement and spatial ability but also enables learners with deeper understanding by creation of appropriate mental models.

CONCLUSION

This study has implications in terms of holistic development of skills of future researchers/ leaders. Based on the kind of Instructional strategy a teacher uses in classroom, the understanding and achievement in chemistry of learners is established. Using interaction integrated with dynamic visualisations; the learning becomes more concrete. These learners are the future leaders, scientists who will contribute to the nature and society. So if we introduce effective instructional strategies for teaching chemistry, then ultimately not only the learning outcomes, but their abstract understanding of concepts would also improve. Holistically it would nurture their skills; including the spatial skills. Such learners could for example come up with Green chemistry ways or lesser energy spending methods of using lesser chemicals in laboratories and getting maximum output. The idea is that it could lead to generation of better performers and future researchers.For effective learning to occur, the external stimulus in form of simple instructions, experiences or in form of multimedia presentation plays a vital role. The principles of multimedia learning need to be considered while designing the multimedia based lessons or instructional strategies to improve the learning outcomes significantly. The various instructional strategies used must be relevant with respect to the kind of multimedia presentations. The results from this study have a direct implication for the use of I.I.I.D.V as an Instructional strategy. This clearly explains the role of Educators in implementing the technologically interactive classrooms as per NEP 2020 framework.

BIBLIOGRAPHY

Abanikannda, M.O. (2016). Enhancing Effective Chemistry Learning Through Hypermedia Instructional Mode of Delivery. European Journal of Educational Research, 5(1), 27-34. doi: 10.12973/eu-jer.5.1.27

Akaygun, S. (2016). Is the oxygen atom static or dynamic? the effect of generating animations on students' mental models of atomic structure. Chemistry Education Research and Practice, 17(4), 788–807. https://doi.org/10.1039/c6rp00067c

Ardac, D., & Akaygun, S. (2004). Effectiveness of Multimedia-Based Instruction That Emphasizes Molecular Representations on Students' Understanding of Chemical Change. Journal of Research in Science Teaching, 41(4), 317–337. https://doi.org/10.1002/tea.20005

AkdenizCelal. (2016). Improving the teaching process. Instructional Process and Concepts in Theory and Practice, XXVII, pp. 57-105, DOI 10.1007/978-981-10-2519-8_2, Retreived from www.springer.com/cda/content/document/cda.../9789811025181-c2.pdf?SGWID.

Bodemer, D., Ploetzner, R., Bruchmüller, K., & Häcker, S. (2005). Supporting learning with interactive multimedia through active integration of representations. Instructional Science, 33(1), 73–95. https://doi.org/10.1007/s11251-004-7685-z

Cheon, J., Chung, S., Crooks, S. M., Song, J., Cheon, J., Chung, S., Crooks, S. M., Song, J., & Kim, J. (2014). An Investigation of the Effects of Different Types of Activities during Pauses in a Segmented Instructional Animation. Journal of Educational Technology & Society, 17(2), 296–306.

Hegarty, M., Kriz, S., Cate, C., Cognition, S., Hegarty, M., Kriz, S., & Cate, C. (2003). The Roles of Mental Animations and External Animations in Understanding Mechanical Systems. 21(4), 325–360.

Habraken, C. L. (1996). Perceptions of chemistry: Why is the common perception of chemistry, the most visual of sciences, so distorted? Journal of Science Education and Technology, 5(3), 193–201. https://doi.org/10.1007/BF01575303

Karacop, A., & Doymus, K. (2013). Effects of Jigsaw Cooperative Learning and Animation

Techniques on Students' Understanding of Chemical Bonding and Their Conceptions of the Particulate Nature of Matter. Journal of Science Education and Technology. https://doi.org/10.1007/s10956-012-9385-9

Kavya Alse and Anurag Deep. (2016). Active Learning. https://doi.org/10.1007/978-1-4419-9863-7_605

Khalil, M. K., & Elkhider, I. A. (2016). Applying learning theories and instructional design models for effective instruction. Advances in Physiology Education, 40(2), 147–156. https://doi.org/10.1152/advan.00138.2015

Mayer, R. E. (1995) A generative theory of textbook design: using annotated illustrations to foster meaningful learning of science text. Educational Technology Research and Development, 43, 3 1-43.

National Education Policy, 2020, Ministry of Human Resource and Development, Government ofIndia.Retrievedfromhttps://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf

SenguptaAparajita, Ajithkumar C., Aggarwal J.C.& Kumar Harish. Development of Higher Education in India and Professional Development of Teachers.Savitribai Phule Pune University, School of Open Learning, M.A Education, Second year. Sept 2021. Vikas Publishing House, New Delhi.

Williamson Vickie M. & Abraham Michael R.(1995).Effects of Computer Animation on the Particulate Mental Models of College Chemistry students.Journal of Research in Science Teaching, Vol 32, No.5, pp.521-534.