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Full Length Research Paper

Is 3D just an addition of 1 to 2 or is it more enhancing than 2D visualizations?

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There have been much reports of usefulness as well disadvantages of 3D environments in science teaching and learning when compared with 2D visualizations. The present study investigated the relative effectiveness of 2D and 3D visualizations on Nigerian Senior Secondary One students' understanding of molecular structure and nomenclature in organic chemistry. Quantitative data were generated using validated structured short answered questions. The instrument was administered before and after two intact groups of students (n = 60, 30 in each) were treated with 2D and 3D software supplemental following a conventional teaching. Treatment of the pre-test and post-test data using t-test statistic indicated no significant difference between the two groups even though the mean score of the 3D group was a little higher. In addition, the closeness of the mean scores which suggest that both 2D and 3D were good supplemental and the recommendation is that both should be used in teaching organic chemistry in schools. The excitement with which the students embraced 3D visualizations prove they might be more enhancing if students get used to the skills involved and the ability to fully comprehend them.

Key words: 2D, 3D visualizations, effectiveness, organic molecules, structures and nomenclature.

INTRODUCTION

For a long period of time science teaching and learning were done mainly through a system of two-dimensional notations and flat structures on paper. Up till now paper and chalkboard presentation of organic molecules are the usual practice in many classrooms. In rare instances, this practice is supplemented with the use of concrete three-dimensional models like ball and stick. However, with the advent of ICT and internet facilities, teaching and learning in science education are being revolutionized with 3D environments, simulation and visualizations. Many see this innovation as not just two plus one but that 3D visualizations are enablers of learning (Raineri, 2001; Striegel, 2000; Barak, 2007). The advocates amplified the advantages of this state-of-the-art computer technology over 2D visualizations. They are reported to have improved the attitudes of students toward chemistry (Barak and Dori, 2005), that they are effective in modeling abstract concepts, and could make concepts that seem difficult for students to understand a tangible manipulable concrete (Dalgarno et al., 2003; Strangman et al., 2003). It is also argued that 2D illustrations remove too much information from the real structures and make impossible spatial matching of structures (Romili et al., 2003; Barak and Dori, 2005) which 3D visualizations have taken care of. It is equally documented that understanding and achievement in chemistry and particularly molecular and stereochemistry are closely related to 3D visualization ability (Barak and Dori, 2005; Kelly and Jones, 2005; Tuckey et al., 1991; Tuckey and Selvaratnam, 1993; Tyversky, 2001). Gabel (1999, 2004), Coll and Treagust (2003), Dori and Hameiri (2003) and Dori et al. (2003) are of the opinions that a large amount of chemistry content at whatever level deals mainly with

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studies at micro level. These entities like atoms, ions, molecules etc according to Tasker and Dalton (2006) are inherently three-dimensional, and are being presented in science classrooms by a system of dimensionally-deficient 2D drawings thereby, constituting a major hurdle for aspiring chemists. The argument in favour of 3D visualizations is stronger than those listed here. However, there are also arguments against this-state-of-art technology which go in favour of the traditional 2D flat structures, paper and chalkboard illustrations.

One such argument is that, students are more familiar with 2D drawings and illustrations as presented in textual materials they frequently interact with and that these 2D illustrations are more suitable for quick comparison when teaching structures in organic chemistry (Gervasio, 2004; Schmidt-Ehrenberg et al., 2002) Some have argued that students may not have a full grasp of 3D nature on the commonly available flat computer screen thereby generating more misconceptions and ambiguity than reducing them (Sinex and Gage, 2004; Gervasio, 2004). Beside these pedagogical issues, there is also the economic aspect, making the use of this technology in science education rather too expensive for many schools, particularly in developing nations to bear (Bon, 2007). The problems of access, poor internet connectivity and digital divide are there, making 3D viewing on computer almost impossible in many nations' schools. Rather than be enablers of learning as advanced by the advocate they are seen to be more of inhibitors (Barak, 2007). Here lies a problem or confusion.

The question is that; which of the method between 2D and 3D is really more effective in enhancing total learning outcomes that are the goals of science education in students? This is the problem that this study was designed to investigate. The major hypothesis is that 3D visualizations will not enhance students' performance better than 2D visualizations.

Visualization software emerged in the late 1980s (Brown, 1988; Stasko, 1990) for the purpose of creating and interactively exploring graphical representations of computer science concepts. It is the transformation of data or information into pictures and graphics in different dimensions that make human brains able to process such information. It is a tool to make sense of the food of information in today's world of computers (Kunle and Alam, 2010; Schroeder, 1997; Songbo, 2004). As mentioned earlier, study at micro level, nano-chemistry, or structures that are not physically accessible to human senses rely on visualizations. Researches into these physically inaccessible structures benefit from computer reconstruction and rendering of data captured by imaging techniques or generated by simulations. Using visualize-tion technologies, data can be represented in two-, three, or even higher dimensions (Bhaniramka et al., 2000). Furthermore, users can change the value of parameters when visualizing data interactively such that more useful information can be gained from such visualization. The power of visualizations to illustrate and explore phenolmena in chemistry teaching particularly the teaching of organic structures lie in the convenience of building molecules of any size and colour in a number of presentation styles (Barnea and Dori, 2004). As such they find valuable use in teaching the structures of organic molecules. The use of 2D structures on the other hand had long been the practice in many classrooms even till present time. Teachers' use of dashes and wedges, line-segment and condensed formula is prevalent (Ealy, 2004; Ramsay et al., 2002). Efforts to make them equally effective in teaching and learning were supported by the use animation for transformation (Kozuma and Russell, 2005; Thatcher, 2006) Animation in form of rocking can transform a static structure of 2D to increase the 3D scene perception. This technique could be used to create an illusion of 3D without any special device. Chalk-board, 2D drawing programs, pseudo 3D programs and physical models have been found to be effective teaching tools used to a large extent by most chemistry teachers and lecturers (Coll and Chapman, 2000).

While many students have found encouragement using 3D visualizations and colourful molecular images to practice the use of different representations on computer (Barak and Dori, 2005; Barak and Hussein-Farraj, 2009; Ealy, 1999; Tasker, 2004), others were found to be more familiar with the use of dashes and wedges to represent 2D and semi 3D views, ball and spoke, ball and wire, skeletal and structural formulae which are widely used in chemistry courses (Ealy, 2004). According to Schmidt-Ehrenberg et al. (1997) students in the latter category who had mastered skeletal formulae, found it a lot easier to write structures of hydrocarbons. They were found to perform well irrespective of whether the teacher used 3D ball and stick models in real laboratory or in computer laboratory through visualizations and animation. The students' performance might have also been enhanced because the teaching, the learning and response to paper and pencil tests used in schools follow the same pattern of drawing structures with 2D representation. This reinforces our earlier hypothesis whether there is significant difference in students' performance on using 2D and 3D illustrations and visualizations in organic chemistry, particularly in drawing and naming of hydrocarbon molecules (Oloruntegbe and Alam, 2010).

METHOD

The design employed in this study is pre-experimental of the pre-test post-test control group type. The population consists of Senior Secondary One (SS I) chemistry students in all the secondary schools in Ondo State. But being an experimental research, the sample was drawn from one urban school in the state. The 60 Chemistry male and female students were randomly assigned to two groups, 2D and 3D visualization groups. The two groups were engaged in supplemental learning using Teaching and Learning Organic Structure and Nomenclature with Software (CDs) in addition to the conventional classroom teaching. After teaching, the first group used 3D viewers while the other used 2D skeletal

Table 1. The mean, standard deviation and t-test values for pre-test and post-test scores 2D and 3D visualization groups.

Variable	n	$\bar{X}$	SD	df	t_{cal}	t_{tab}	Level of significance
Pre - test	30	25.3333	7.9344	58	3.996	2.000	0.05
Post-test	30	65.5556	11.5415				

Significant at 0.05.

Table 2. The mean, standard deviation and t-test of 2D and 3D groups' scores.

Variable	n	$\bar{X}$	SD	df	Sig	t_{cal}	t_{tab}
2D	30	58.6867	8.6603	58	0.633	0.924	2.048
3D	30	60.1867	11.1430				

formula and animation in computer laboratory one after the other. The groups served as control for one another. Four instruments were used for data collection. The first was structured short answer questions on drawing, naming and identifying hydrocarbon molecules and isomers. They were prepared with accompanied marking scheme that awards one point mark throughout the questions. The second was structured four weeks lesson plans which were used in both the groups. The third was a CD-ROM of 3D organic molecular models of alkanes, alkenes and alkynes, and their derivatives and isomers. The structures were constructed into ball-and-stick; wire-frame and space-filling models that can be viewed on desktop screen. The last one was a CD-ROM of flat surface 2D structures of the same molecules. The last two constituted 3D and 2D visualizations and were designed by Command College Enugu in collaboration with Project Development Authority (PRODA) also in Enugu. PRODA is one of the science and technology research centers established by Federal Government of Nigeria for the purpose of producing science curriculum materials and software for use in schools.

The lesson notes were highly structured as they contained all the relevant information on strategies, steps and evaluation questions that teachers need to teach the topics. The CD-ROMs were supplemental self learning packages used by the groups in the computer laboratory. However, the number of periods and time of exposures in both groups were the same. Both groups proceeded to computer lab after each lesson.

A "panel of expert" technique was employed in establishing the content and construct validity of the instrument. This involved subjecting the instruments to analysis by experts, two academics in chemistry, the field that the instruments examined [35, 36]; two in test and measurement and the remaining two were secondary school chemistry teachers. They agreed that the question items covered the objectives of the curriculum and were good. Test-retest determination of the test items with sample of 20 SSS 1 chemistry students outside the sample yielded 0.78 reliability coefficients.

The two groups of students were taught by one of the regular school chemistry teachers for three periods of one hour each a week for four weeks. After each period, the groups were in turn subjected to another thirty minute interactivity session with 2D and 3D CD-ROMs. The procedures were closely monitored to the satisfaction of the researchers. The test items were administered before and after the four week sessions and marked by the same teacher using the prepared marking scheme to generate pre-test and post-test data. The data collected were analyzed using t-test statistic. The use of the students' regular chemistry teacher was to ensure uniformity and eliminate biases.

RESULTS

The results were presented as tests of two hypotheses (HO):

HO_1: There is no significant difference in the pre-test and post-test mean scores of 2D and 3D visualization groups. As shown in Table 1, the $t_{calculated} > t_{table}$ (3.996 > 2.000), therefore the hypothesis of no significant difference was rejected. This means that there is difference between the pre-test and post-test scores. The difference can be attributed to the treatment. In other words the treatment had facilitative effect, hence the difference. The second hypothesis test significant difference between the two groups.

HO_2: There is no significant difference between post-test scores of students treated to 2D and 3D visualizations. Table 2 shows that, the $t_{calculated} < t_{table}$ therefore the hypothesis of no significant difference is upheld, meaning that there is no significant difference in the mean scores of both groups. Comparison of the mean scores of both groups, however, shows that 3D ($\bar{X}$ = 60.1867) is greater than 2D ($\bar{X}$ = 58.6867), the result is, however, not statistically significant.

DISCUSSION AND CONCLUSION

The results of this study show no significant difference in the performance of students of the two groups. Although, the mean score of 3D students was higher than that of 2D group, the difference was not statistically significant. The closeness of the two mean scores show that the two treatments were good supplemental. Earlier study with a control group and in another setting (Kunle and Alam, 2010b) shows similar trend of close scores but with 2D performing better. This trend shows that the use of 2D and 3D visualizations enhanced performance in organic chemistry and they should be used to supplement one another. Observations during the interactive sessions revealed that the 3D students were more excited and wished to stay longer on the session than the 2D students. The 2D group on interview explained that they found only little difference between the interactive session and the conventional teaching. However, they seemed to get by and performed equally well perhaps because of their familiarity with the plain structures as found in Ealy (2004) and Schmidt-Ehrenberg et al. (1997) studies and that the tests response was also of the same nature as 2D.

That the scores of the two groups were closed suggest the need to employ both 2D and 3D visualizations in science teaching as this would enable the students to have compensation of whatever that is missing in the other. The conclusion based on the quantitative data and treatment used in this study is that none of the two visualizations was superior to the other. However, with the interest and excitement shown by students, the use of 3D environments might lead to more enhancements if they get used to the skills involved in spatial visualization.

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