THE INFLUENCE OF 3-D MODEL BIOLOGICAL SYSTEMS IN UNDERSTANDING CELLULAR DIVERSITY

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DOI: https://doi.org/10.54476/ioer-imrj/009169

ABSTRACT

This study focused on the influence of instructional 3D Model Biological Systems (MBS) in understanding cell diversity. It determined the academic performance of the students according to content knowledge, quality of artwork, and communication skills; and to determine what group of learners benefited most in using 3D instructional models. It involved 30 second year high school students in a private school in Imus, Cavite. Data were treated statistically with arithmetic mean, dependent t-test, gain scores, Pearson r Product Moment of Correlation, one-way analysis of variance (ANOVA), F-test, and Tukey multiple comparison test. Findings revealed that the use of 3D instructional cell models was effective in improving the academic performance of the students in terms of content knowledge, quality of artworks, and communication skills. The computed mean difference of 3.60 and t-value of 10.998 for 29 degrees of freedom, which is 2.756 at .01 level of confidence, showed a significant difference from their pre-test and posttest scores. This implies that participants obtained much learning on cellular diversity using 3D cell models. All groups of learners benefited most from using 3D instructional cell models thus students' academic performance in Biology has improved. Thus, the study recommends that 3D instructional models should be used in teaching professional Science subjects such as Biology. More so, similar studies should also be conducted not only in the Biology subject but also in Chemistry and Physics courses. Other 3D Model Biological Systems can be used for instruction to Senior High School Science majors and college students.

Keywords – *Cellular Diversity, 3D Model Biological Systems, General Biology, Cell Models.*

INTRODUCTION

The continuous innovations and inevitable advancement of scientific technology, genomics, proteomics, nanotechnology, micro array technology, among others, has brought a dramatic transformation in the objectives of science teaching and learning at all levels and within all disciplines. The focus has shifted from teaching students a foundation of scientific facts to teaching them how to deeply understand both concrete and abstract concepts. This transformation requires a significant change in the attitude and approach of teachers and students as well as in the methods and strategies needed to teach the extensive course content of biological sciences. What counts more in biological sciences is the ability to inquire rather than to simply acquire scientific truths.

When difficult cell concepts and abstract thoughts are concerned, students need opportunities for experimentations and observations of the phenomenon being studied. In many cases, this is not possible. Only few phenomena are available for observation because of different reasons such as size, risk and time. To overcome these problems, teaching tools that imitate natural phenomenon, like experiments and simulations are used in biological sciences classes.

Conventional teaching tools contribute much to the learning process, but they have certain limitations. Full advantage of the different learning areas may not be done. A simple compound microscope, for instance, reveals a real close-up image of the cells. However, it does not give the students a full view of the dimensions of the cell structures. Moreover, students' interactions and collaboration inside the classroom are limited especially when these apparatuses are not easily available in their schools. It has also been accepted that traditional teaching approach is frequently a passive experience for students. Watching a film presentation or seeing a picture/chart of a plant cell reveals many aspects but not enough to explore the concepts, making the students passive, less inquisitive, no initiative, and less interactive.

Describing and analyzing concepts are not sufficient for the study of cell diversity. The teacher needs to teach concepts in a qualitative manner first then use multiple representations of the subject and let formal representations follow. The study of cell diversity requires multidimensional examination of the topic, and the use of instructional tools is important. Many science educators recognize the importance of using instructional tools, one of which is the use of varied visual aids like pictures, real specimens and three-dimensional (3D) models be it a solid model or an electronically 3D (e-3D) models on the internet. These three-dimensional models are scaled replicas of real objects and often used when the real things are not available because their size is either too small or too large (Corpuz & Salandanan, 2003). Teachers as well as educational technologies have been designing, constructing and using for quite some time instructional 3D models as tools for teaching. Bioengineers modified these instructional 3D models in more complex strategies to demonstrate more subtle and sensitive issues in many science disciplines.

The uses of 3D models are evident in instruction such as mechanical models for teaching kinematics and dynamics, ball-and-stick models of complex molecules for teaching chemistry, and animal skeletons for teaching biology. Recently, pictures from electron microscopes and instructions for the construction of 3D models with easy to acquire materials have surfaced in the internet as teaching tools. This has offered a range of opportunities in developing teaching and learning strategies. Of particular note in this study is the need to establish new and better ways to enhance students' academic achievement. The employment of hands-on activity displays the uniqueness and growth of each student over a period of time (Mayer, 1989). It is an experiential level of interactive learning where the teacher discovers the students' hidden talents and complex skills, like communication skills and creativity. According to Wilson et al. (2020), models allow students to transform their perceptions of biology classes from memorization and pen-and-paper tests to representation and analysis of dynamic, multidimensional, interconnected, and complicated biological systems; thus, it has evolved into a strategy for how we provide instruction and a way of introducing and integrating new concepts together.

Teaching cell structure and functions has been traditionally approached through the use of illustrations and cut-away drawings. One way to show and explain cell structures and functions is to interactively utilize 3D models in the classroom. This interactive experience will be more appealing to the students, encouraging meaningful interactive discourse and promoting the learning of core concepts in cell biology (Mikropoulos et al., 2003; Johnston et al., 2018). Likewise, employing instructional 3D cell models could also present a good improvement in the assessment of the students' understanding of cell especially when 3D cell models are used as a group task or hands-on activity for the students. The hands-on activities of constructing various 3D cell models highlighted the importance of the learner being actively involved in the learning process and the teacher being the facilitator who encourages learners to improve their performance outputs (Taber, 2017).

Several studies have shown that the use of instructional 3D models of biological systems as a strategy is helpful in the improvement of various aspects of students' learning as well as teachers' instruction. Evangelista et al. (2014) explored the development of a prototype model "Biokit" based on the K-12 curriculum for Science Grades 7 and 8 and found this tool to be efficient for classroom instruction. Rodenbough et al. (2015) studied the use of instructional aids that enable the transformation of actual crystallography files into 3D models of diverse unit cells. Segarra and Chi (2020) discovered the combination of macromolecule 3D-printed models and open-source molecular modeling that allows students to remember prior information and utilize it to new situations.

Conventionally, instructional models were just used as tools of science teachers inside the classroom, so its potential to dig up students' abilities was limited. But as science educators feel the need for students to understand scientific breakthroughs, they continue to explore more ways to use these tools inside the classroom. Likewise, students nowadays are more participative; thus, through constructing their own 3D models in various ways, their learning becomes enjoyable even if these concepts are difficult to understand.

OBJECTIVES OF THE STUDY

This study was designed to determine the influence of the 3D Instructional Cell Models of Various Model Biological Systems in understanding cell diversity. In accordance, it sought to: 1.) determine 3D Instructional Models of various model biological systems influence the academic performance of college students according to their content knowledge, quality of artworks, and communication skills. 2.) evaluate the group of learners who benefited most using the 3D Instructional Cell Models; high ability, average ability, low ability.

METHODOLOGY

This study employed the descriptive-evaluative design to determine the influence of the 3D Instructional Models of Model Biological Systems in understanding cellular diversity. The study was conducted in a private school in Imus, Cavite. This research was composed of thirty (30) second year high school students. The class was grouped into six (6), with group one having four (4) members, groups two, three, four, and five, with five (5) members; and group six, with six (6) members. The groupings were formed according to their Base Scores that were derived from the second quarter grades in Biology.

A 50-item pre-test and post-test on cell development of cell theory, cell types, cell parts and functions, and cell environment were constructed by the teacher and was based on the required textbooks, reference books, workbooks, course guides, course objectives and sequence of the topics on cell parts and function to determine students' improved rating before and after exposure to lectures, discussions and activities on the said topics. To provide the researcher a comprehensive knowledge of the nature of the test criterion, she familiarized herself first with the theoretical constructs directly related to the tests. The researcher also surveyed several biology textbooks, course guides, course objectives, scope and sequence and other materials pertinent to the subject. To determine the concepts which present the nature of the variable being measured, a table of specifications was constructed.

Rubrics were used to objectively assess the performance products of the participants. Likewise, they provided information on how the construction of 3D cell models contributed to the development of the participants' understanding of cell diversity. The second quarter grade sheet of the students was utilized as a basis to rank the students in their class standing. Likewise, the grades were used as a basis to group the participants for the interactive hands-on activity of 3D cell model construction.On the other hand, the first drafts of 50 multiple-choice items of both tests (pre-test/post-test) were prepared. The corresponding items dwell on the same concepts as presented in the table of specifications. The first draft of tests was shown for face and content validation to the advisers and other biology teachers. Then, test items were validated to measure the accuracy and appropriateness of every variable used in the questionnaire. It was conducted by a group of evaluators composed of the advisers, teachers, and test construction expert. The tests were adjudicated according to the appropriateness or suitability of the items, relevance, clarity of language used, and correctness of sentences (Sevilla et. al., 1992).

Likewise, the test reliability was established using the split-half technique. This was done by splitting the test into two: the odd numbered items as X, and the even numbered items as Y. The scores in the X variable were correlated with the scores in the Y variable through the Pearson Product-Moment Correlation. The computed r value of the test is 0.80 and to obtain the reliability, a correlation formula was applied using Spearman-Brown formula. The r value of the test is 0.89 which indicates that the tests have a high correlation. The first draft of rubrics was shown to English, Science and Art teachers of the school for suggestions on content and were then submitted to the advisers for comments. After a series of questions and deliberations, the instruments were subjected to face and content validation. In response to their suggestions, several revisions were made especially on the content, scale and structure of the rubrics. The final forms of rubrics were presented to evaluators who unanimously approved that the instruments were valid and suitable based on the criteria. Significantly, arithmetic mean, dependent t-test, gain scores, Pearson r Product Moment of Correlation, one-way analysis of variance (ANOVA), F-test, and Tukey multiple comparison test were used as statistical tools in this study.

RESULTS AND DISCUSSION

1. Content Knowledge

The gain scores from pre-test to post-test were computed for each student by subtracting each student's pre-test score from his or her post-test score. The mean was used to measure the scores of the students in various parameters.

As shown in Table 1, the gain scores were all positive. This depicts that all the groups had higher post test results. The high ability group had the highest mean gain score, 15.11, which means that students from this group acquired more knowledge during instruction.

Table 1
Content Knowledge Results of the Students

Group	Pre-test	Post-test	Gain
High Ability	24.33 (3.35)	39.44 (3.47)	15.11 (4.20)
Average Ability	21.90 (4.23)	31.40 (4.40)	9.50 (4.43)
Low Ability	16.82 (5.23)	26.18 (4.75)	9.36 (5.99)
Overall	20.77 (5.32)	31.90 (6.88)	11.13 (5.51)

Note: Standard deviations are enclosed in parenthesis.

The average ability group had a mean gain score of 9.50, while the low ability group had the lowest mean gain score of 4.36. The mean gain scores of the average ability group and the low ability group had a small difference of 0.14, still this illustrates that there was knowledge acquired during the instruction. The overall mean of students' gain score is 11.13. The results showed an improvement in the students' content knowledge after exposure to 3D instructional models as a new strategy.

The pre-test, post-test and gain scores of the three groups of students showed variations. The low ability group had the highest standard deviation, 5.99. The lowest standard variation is observed in the high ability group, 4.20. The standard deviation of the average ability group is 4.43, a little bit higher than that of the high ability group. The overall standard deviation is 5.51. This trend is shown in the graph (Figure 1).

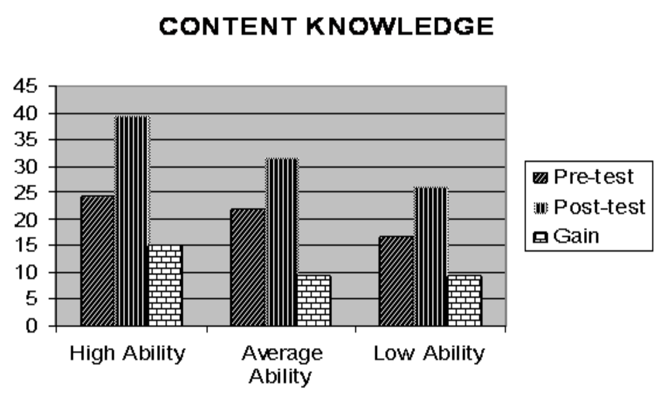

Figure 1. Means in the Pre-test, Post-test and Gain Scores of the High, Average and Low Ability Groups of Students

It can be seen from Figure 1 that the high ability group obtained higher means for the pre-test and post-test compared to the means of the pretest and post-test of the average and low ability groups.

The mean of the gain scores of the high ability group was also much higher compared to the gain scores obtained by both the average and low groups of students.

2. Comparison of the Pre-test and Post-test Results of the Students

Table 2
Comparison of the Pre-test and Post-test Results of the Students

Source	Mean Difference	Standard Deviation	df	t-value (computed)
Post-test & Pre-test	11.13	5.51	29	11.07*

* $p < 0.05$

Based on Table 2, the t-test pair wise analysis showed a mean difference of 11.13. The computed t-value of 11.07 was greater than the tabulated t-value of 2.045 at $p < 0.05$ with df of 29. This implies that the difference between the pre-test and the post-test mean scores was statistically significant. Indeed, the students had a marked improvement in the content knowledge on cellular diversity. Results on this particular skill support the notion that instructional 3D models promote almost 90% retention of knowledge.

Generally, the results proved that, indeed, 3D Instructional Models significantly improved the students' content knowledge on cellular diversity. The students obtained good scores because the items answered in the tests were arranged during their participation in motivation, instruction, and cooperative group activities. Using 3D instructional models, students understood better the concepts on development of cell theory, cell types, cell structure and functions and cell environment; thus, they attained higher scores in the post-test administered at the end of the study. The 3D Instructional Models can really provide impact on the attention and motivation and sustain interest and enhance students' learning capabilities (Stroble et al., 2009). Likewise, it has also been established that by using 3D instructional models during learning procedures, students achieved higher learning gains (Dori & Kaberman, 2012).

3. Quality of Artworks

Assessing students' mastery does not always involve a paper-pencil test. In a dynamic class, a teacher can use instructional models to know her students' quality of artworks better and students may likewise manifest their gained knowledge and understanding of scientific concepts (Strober et al., 2009). With the guidance of the teacher, students prepare models, teach their peers, give an oral demonstration, design an experiment and use visual aid presentations. Thus, students were tasked to produce the various 3D cells models after instruction phase. The 3D cell models were submitted as their performance artworks (Figure 2).

Figure 2. 3D cell models of students

4. Quality of Artworks Results of the Students

As exhibited in Table 3, the average grades of the students increased from the first to the fourth performance artworks. The high ability group got an average rating of 89.44%; the average ability group, an average of 89.90%; and the low ability group, an average of 89.45%. The overall mean of students' quality of artworks is 89.60%.

Table 3
Quality of Artworks Results of the Students

Group	Assessment 1	2	3	4	Average
High Ability	87.33 (1.87)	88.00 (2.18)	89.67 (2.18)	92.44 (1.59)	89.44 (1.33)
Average Ability	87.20 (1.69)	87.60 (2.17)	90.30 (2.36)	92.70 (1.95)	89.90 (1.66)
Low Ability	87.00 (1.73)	87.45 (2.12)	90.00 (2.45)	92.82 (1.78)	89.45 (1.51)
Overall	87.17 (1.70)	87.67 (2.10)	90.00 (2.27)	92.67 (1.73)	89.60 (1.48)

Note: Standard deviations are enclosed in parenthesis

The quality of artwork averages of the three groups of students showed variations. The average ability group had the highest standard deviation, 1.66. The lowest standard variation was observed in the high ability group, 1.33. The standard deviation of the low ability group was 1.51, lower by 0.15 than that of the average ability group. The overall standard deviation was 1.48. Figure 3 shows the trend of the results on the quality of artwork of the three groups.

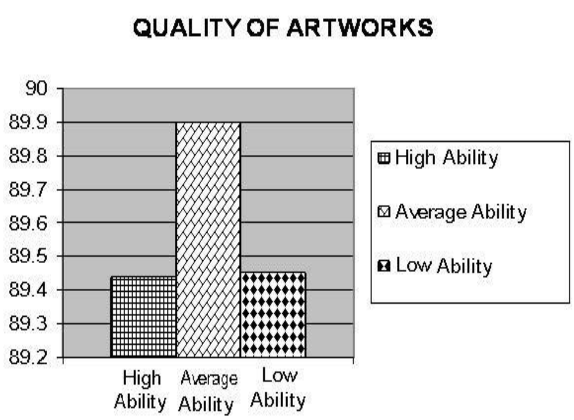

Figure 3. Quality of Artwork Results of the High, Average and Low Ability Groups of Students

Figure 3 indicates that the average ability group appeared to be more creative in terms of art works. These findings were fortified when most of their constructed 3D models were improving based on the set of criteria indicated in the rubrics. The data seem to support the hypothesis that the use of the 3D Instructional Models of Biological Model Systems enhances the quality of artworks of the students on cellular diversity. However, there were differences in the scores of the students.

To determine the significance of the differences in students' quality of artwork ratings for the four performance products, the F-test using one-way analysis of variance (ANOVA) was employed. The ANOVA summary of results is shown in Table 4.

Table 4
ANOVA Summary of the Quality of Artworks of the Students

Source	Sum of Squares	df	Mean Squares	F value (computed)
Between Groups	571.84	4	142.96	2.43
Within Groups	510.70	145	3.52	
Error	1082.54	149		

* $p < 0.05$

As displayed in Table 4, it can be noted that the computed F-value is 40.59. It was much greater than the tabulated value 2.43 at p-value of less than 0.05 with the df of 4. This is highly statistically significant. It means that the quality of students' artworks significantly increased/ improved with the use of the 3D models.

Table 5
Significance of Mean Differences Among Various Assessments by the Tukey Multiple Comparison Test (Quality of Artworks)

Assessment	1	2	3	4
1	0.00*			
2	0.50*	0.00*		
3	2.83*	2.33*	0.00*	
4	5.50*	5.00*	2.67*	0.00*

* $p < 0.05$

Table 5 shows that the Tukey multiple comparisons test revealed that the difference of all the pairs being compared was statistically significant. This finding indicates that 3D instructional models provided the students the element of realism which is of great help to high school students whose ideas about cells are abstract, thereby making it difficult for them to understand the concepts. The hands-on activities in constructing 3D models generated cooperation and enthusiasm among the groups of students which motivated them to improve their grades. Noble (2007), states that through cooperative activities, recognition, and rewards are essential. It encourages innovative group members to be patient when assisting and pushing back on underperforming teammates. Hence, the use of 3D models is driven by trends in the discipline where buildings or works of art are replacing more traditional "pen and paper" methods.

5. Communication Skills

The written journals of the students were scored through the use of rubrics. The mean was used to show the average ratings of the groups. Data are revealed in Table 6.

Table 6
Communication Skills Results of the Students

Group	Assessment 1	Assessment 2	Assessment 3	Average
High Ability	88.89 (2.26)	91.67 (3.32)	90.44 (1.33)	90.44 (1.59)
Average Ability	85.60 (1.71)	87.10 (2.69)	90.60 (1.51)	87.80 (1.32)
Low Ability	82.91 (3.53)	84.91 (2.17)	90.36 (1.36)	85.82 (1.54)
Overall	85.60 (3.57)	87.67 (3.85)	90.47 (1.36)	87.87 (2.39)

* $p < 0.05$

As revealed in Table 6, the average grades of the groups based on the three performance products showed marked improvement in communication skills. The high ability group got an average rating of 90.44%; the average group, a rating of 87.80%; and the low ability group, an average rating of 85.82%. The overall average of students' communication skills is 87.87%.

The communication skills averages of the three groups showed variations. The high ability group had the highest standard deviation, 1.59. The lowest standard variation is observed in the average ability group, 1.32. The standard deviation of the low ability group is 1.54, slightly higher by 0.05 than that of the high ability group. The overall standard deviation is 2.39.

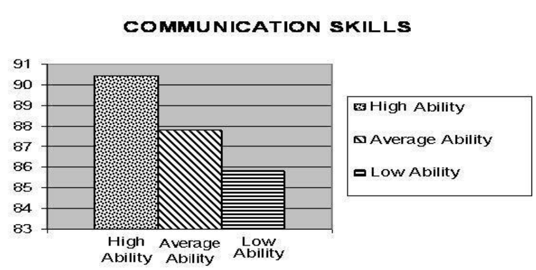

Figure 4. Communication Skills Results of the High, Average and Low Ability Groups of Students

Figure 4 illustrates that the high ability group obtained the highest mean (90.4%) for the said skill. The average ability group had an average of 87.80%, while the low ability group had 85.82%. The figures indicate that among the groups, the high ability group showed a better way of expressing their views and ideas through their journal than the two other groups. The data seem to support the hypothesis that the use of 3D Instructional Models of Biological Model Systems enhances the communication skills of the students. However, there were differences in the scores of the students in each group.

6. Summary of the Communication Skills of the Students

To determine the significance of the differences in the ratings students' quality of artwork for the four performance products, the F-test using one-way analysis of variance (ANOVA) was used. The ANOVA summary of the results is shown in Table 7.

Table 7
ANOVA Summary of the Communication Skills of the Students

Source	Sum of Squares	df	Mean Squares	F value (computed)
Between Groups	357.96	2	178.9	18.25*
Within Groups	853.33	87	9.81	
Error	1211.29	89		

* $p < 0.05$

The preceding ANOVA Table shows a significantly computed F-value of 18.25. The tabulated value 3.10 registered a p-value of less than 0.05 with the df of 2. This result suggests that the highest and the lowest communication skills mean scores differ significantly, implying significant increase in the mean scores. It means that communication skills were enhanced using 3D instructional cell models in the classroom.

Table 8
Significance of Mean Differences among Various Assessments by the Tukey Multiple Comparison Test (Communication Skills)

Assessment	1	2	3
1	0.00*		
2	2.07*	0.00*	
3	4.87*	2.80*	0.00*

* $p < 0.05$

Table 8 highlights that the Tukey Multiple Comparison Test results showed a significant difference among the means. The mean of the second assessment is substantially higher than the first assessment but lower than that of the third assessment. These data indicate that the performance products of the three groups had satisfactorily met the standards of excellence. The journals provide additional proof that, apparently, by the use of 3D instructional models of model biological systems when employed efficiently, students' understanding of cellular diversity was enhanced. The use of 3D models is a way of students representing their unique ideas about the abstract concepts on cellular diversity through written communication. 3D models help students to communicate about real things or phenomena (Grosslight et al., 1991; Augusto et al., 2016).

The findings further show that 3D instructional models contributed to the significant improvement in the participants' communication skills because its interactive nature provides a venue for students to express their opinions in every activity or experiment. Their journals were a way for them to incorporate personal ideas with observation and inferences. Their journals also served as evidence that they gained knowledge of following directions precisely, responding to inquiries truthfully, and organizing their thoughts logically. Also, they gave ample time to purify and clarify their thoughts which led them to make sharp judgments and right conclusions.

7. 3D Instructional Models and Ability of the Students

Table 9

Comparison of Content Knowledge Gains of the Different Groups

Source	Sum of Squares	df	Mean Squares	F value (computed)
Between Groups	203.53	2	101.77	4.065*
Within Groups	675.93	27	25.04	
Error	879.47	29		

* $p < 0.05$

Table 9 shows the ANOVA summary of results. The ANOVA table shows that the two pairs of means differed significantly. Since the mean scores of students with high ability was the highest, it could be said that using 3D instructional cell models in classroom instructions can benefit students with high ability the most. This means that the high ability group grasped more of the concepts about cellular diversity. This result portrays that the students learn best by reading the lessons and by listening to the teacher during lectures. All the groups were attentive, observant and diligent during the course of the strategy.

Table 10

Significance of Mean Differences Among the Various Group Gains by the Tukey Multiple Comparison Test

Group	High Ability	Average Ability	Low Ability
High Ability	0.00*		
Average Ability	5.61*	0.00*	
Low Ability	5.75*	0.14*	0.00*

* $p < 0.05$

Table 10 displays that comparing the mean gain scores of students in the average ability group with the high and the low ability groups indicated no definite distinction. In addition, the mean of the average ability students is not significantly different from that of high and low mental ability students. This suggests that the effect of 3D instructional cell models on content knowledge of students with average ability is quite difficult to determine. Perhaps the three groups of students had combination of learning styles in grasping the concepts of the lesson.

Table 11

Comparison of Quality of Artwork Gains of the Different Ability Groups

Source	Sum of Squares	df	Mean Squares	F value (computed)
Between Groups	1.35	2	0.68	0.30
Within Groups	61.85	21	2.29	
Error	63.20	29		

* $p < 0.05$

Comparing the means of the three ability groups on creativity demonstrated that using 3D can equally benefit these three student groups. The analysis of variance gave an insignificant F-value, 0.30, as seen in Table 12. The analysis indicates that no statistical difference existed among the mean creativity ratings, and the three student groups performed almost equally on this parameter. This is because the groups possessed the kinesthetic learning ability.

Table 12

Comparison of Quality of Artwork Gains of the Different Ability Groups

Group	Source	Sum of Squares	df	Mean Squares	F value (computed)
High Ability	Between Groups	140.08	3	46.69	12.03*
	Within Groups	124.22	32	3.89	
	Error	264.31	35		
Average Ability	Between Groups	197.70	3	65.90	15.59*
	Within Groups	152.20	36	4.23	
	Error	349.90	39		
Low Ability	Between Groups	237.18	3	79.06	19.01*
	Within Groups	166.36	40	4.16	
	Error	403.55	43		

* $p < 0.05$

Looking into quality of artwork ratings for each individual group, a significant increase in the ratings from the four assessment procedures existed. All the F-values (Table 12) indicate p-values which are less than 0.05. This suggests that the mean ratings in the four different assessment procedures for all the ability groups varied significantly. It can, therefore, be stated that the effect of using 3D models was the same for all the groups. In the course of the 3D model construction, all groups were observed to possess the kinesthetic learning ability and that they had different styles of artworks. In all levels of education, hands-on creative art is always a measure of performance. Creative artwork is recognized as a universal trait worth developing (Gompertz, 2015).

Table 13

Comparison of Communication Skills Gains of the Different Ability Groups

Source	Sum of Squares	df	Mean Squares	F value (computed)
Between Groups	106.01	2	53.00	24.07*
Within Groups	59.46	27	2.20	
Error	165.47	29		

* $p < 0.05$

The ANOVA table above presents the comparison of the ratings in communication skills of students in the three ability groups and shows a significant F-value, 24.07, $p < 0.05$. This value suggests that the highest and the lowest mean scores differed statistically, meaning students with high ability performed significantly better in this parameter than their counterparts in the low ability group. Similarly, it can be interpreted that high ability students had better communication skills than any of those in the other two ability groups. This is because the members of the high ability group could express their ideas more clearly both through oral and written manner.

Nevertheless, in terms of the progress of students in the periodic assessment, significant improvement in students' ratings was not observed in the high ability group. It can be noted in Table 14 that the change in the communication skills was more distinct in the low ability group than in the high ability group.

Table 14

Comparison of Communication Skills Gains of the Different Ability Groups

Group	Source	Sum of Squares	df	Mean Squares	F value (computed)
High Ability	Between Groups	34.89	2	17.44	2.93*
	Within Groups	143.11	24	5.96	
	Error	178.00	26		
Average Ability	Between Groups	131.67	2	65.83	15.91*
	Within Groups	111.70	27	4.14	
	Error	243.37	29		
Low Ability	Between Groups	327.52	2	163.76	25.81*
	Within Groups	190.36	30	6.35	
	Error	517.88	32		

* $p < 0.05$

During group works and interviews, the low ability group did not have inhibitions in expressing their feelings and ideas to each other especially to the teacher. It can, therefore, be assumed safely that students in the low ability group gained most from the use of the 3D models in the classroom as far as the art of communication, which is one of the most important skills to master (Tanner et al., 2003).

Overall, it can be stated that the three ability groups improved with the help of 3D cell models. However, among the groups of students, the high ability group benefited most. This was shown by the results of their gain scores and communication skills ratings. For the average ability group, their quality of artworks had the highest improvement. For the low ability group, improvement was minimal and therefore the study suggests that more structured teaching strategy and more interactive hands-on activities be employed to boost their self-esteem inside the classroom. Also, longer periods of study, where differentiated lectures of topics on cell structures and functions, can have repetitions. This way, there will be better retention on the part of the low ability group.

CONCLUSIONS

The present study focused on the influence of 3D Instructional Model strategy in enhancing the understanding of cell diversity among second year high school students in a private school. The 3D biological system models used were composed of virus, bacteria, plant and animal cells. The first problem looked into was the use of 3D instructional models of various model biological systems in enhancing the academic achievement of the students. Three aspects of the academic achievement of the students were considered, namely: content knowledge, quality of artworks, and communication skills.

The results proved that 3D Instructional Models significantly improved the students' content knowledge and quality of artworks on cellular diversity. The gain score results of the students were all positive because the items in the tests they took were aligned with the lesson objectives. Using 3D instructional models, the students understood better the concepts on development of cell theory, cell types, cell structure and functions. and communication skills. Their performance products on quality of artworks and communication skills satisfactorily met the standards of excellence (indicators) based on the rubrics. The high ability group of students benefited most according to their content knowledge and communication skills. On quality of artwork, constructing 3D cell models equally benefited the three groups of students.

RECOMMENDATIONS

Based on the findings and conclusions of this study, the researcher recommends that 3D instructional cell models may well be used in teaching biology. Indigenous materials for constructing 3D instructional cell models may possibly be used. Similar studies using experimental research design involving students in the high school and college levels may be conducted. Similar studies to determine visual, auditory and kinesthetic abilities of the students in the high school and college levels may be conducted. Similar studies in other fields of science like chemistry and physics in the high school and college level may also be conducted as well.

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