Mastering Properties of Organic Compounds through Activity-Based Teaching Technique

Byusa Edwin[1], Kampire Edwige[2] & Mwesigye Rwekaza Adrian[3]

Abstract

Some learners perceive chemistry as a complex subject to learn, saying teaching is boring and not enjoyable. There is a need for making the learning experience more enjoyable to make chemistry easy to understand. This study aims to assess the effect of activity-based teaching techniques compared to the conventional technique on the performance of students in chemistry. The study was quasi-experimental-based research using both pre and post-test, achievement tests. The sample comprised 166 students, as a total number of students in four classes, from a population of 1610 students of the second grade of secondary classes (S2) studying the Properties of Organic Compounds and Uses of Alkanes. Pre-test was conducted, and its data was collected before the intervention, and the post-test was conducted and data was collected after the intervention. Both the descriptive and inferential statistical tests were applied in the analysis. Students' performance gain in chemistry was higher in the treatment classes as the mean value was 6.81 and the standard deviation was 1.66 ($M = 6.81$, $SD = 1.66$) than that of the comparison classes ($M = 6.35$, $SD = 1.78$). However, difference was not significant, $t(164) = -1.73$, $p = .085$. Teachers should be supported in designing physical pedagogical activities for improving learning outcomes in chemistry.

Keywords activity-based teaching techniques; chemistry; conventional teaching techniques; organic chemistry; secondary school

Introduction

Chemistry is a subject that can be taught by applying different strategies. Therefore, the teacher is able to use different teaching approaches during the teaching and learning process of chemistry. This can be done by combining more than one teaching approach in one lesson session or using only one teaching approach for that single lesson session. Some might be teacher-centred, while others are involved in the student-centred approach, which is the preferred worldwide approach. This gives the teachers the only choice of using a student-centred approach. Considering that the choice of teaching technique or method is not random (Duvarci, 2010), teachers need to be supported with the most effective teaching technique for the specific topic instead of generalisation based on what is used easiest or preferred one.

Chemistry is claimed to be a complex subject to teach and learn. For a chemistry teacher to be more successful in chemistry teaching, he or she needs to take into account different aspects that range from chemistry itself in the learning environment and the prior knowledge of the student; then reinforce the engagement of the student in the whole process of teaching and learning (Treagust et al., 2000). Policymakers now

[1]Edwin Byusa, The African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS), University of Rwanda College of Education (UR-CE). (PhD student in Chemistry Education) Email: byedwin@yahoo.fr, https://orcid.org/0000-0001-9602-029X

[2] Kampire Edwige, University of Rwanda College of Education (UR-CE), Department of Mathematics, Science and Physical Education, Email: : edkampire@gmail.com

[3]Associate Professor Mwesigye Rwekaza Adrian (PhD), Department of Educational Foundations and Psychology, Mbarara, Uganda. Email: arm@must.ac.ug

 DOI: https://dx.doi.org/10.4314/ajesms.v17i1.6

recognise student's engagement as important in the teaching and learning process, and students should be brought to the stakeholders' level towards improved learning outcomes (Ashwin & Mcvitty, 2015). Students need to be motivated and interested in the teaching and learning process through a total engagement, linking the learning to the real-life situation for better performance (Sesmiyanti, 2016).

The study conducted in Barbados confirms that chemistry is a tricky subject in lower secondary, and the teaching technique used by teachers is too dull (Ogunkola & Samuel, 2011). Similarly, in Portugal, the students associate their failure in science classes to the quality of teaching (Fonseca & Conboy, 2006). Students are losing little by little interest in learning chemistry (Cardellini, 2012). Furthermore, the observations made in Ethiopia, that chemistry is a complex subject. Still, the reasons given are different; the teaching techniques are among them, and others have to do with students themselves, content, and facilities (Woldeamanuel et al., 2014). The hydrocarbons and alkanols were among the problematic units in S2 chemistry classes (Uchegbu et al., 2016). During different interactions with chemistry teachers, the same observation in Rwanda has informed the primary author that organic chemistry is among the difficult units in implementing the competence-based curriculum (CBC) due to the exigency of the practical sessions in organic chemistry. And most of the time, it is taught theoretically.

This study seeks to determine whether the activity-based teaching techniques can generate better results in students' performance as far as the properties of organic compounds topic of S2 is concerned. The activity-based teaching technique was compared to the conventional teaching technique in S2 chemistry classes. The activity-based teaching technique is defined as a teaching technique whereby learners are actively involved and engaged in the action through hands-on and mind-on activities to attain curriculum objectives (Hansraj, 2017). For this study, the activity-based techniques used involved the physical embodiment of abstraction of the chemical phenomena, conceptual connections, situated cognition and embodied cognition.

This study tested activity-based teaching techniques to respond to the challenges faced by students who perceive chemistry as difficult, tedious and not enjoyable. It supports chemistry teachers to select effective teaching techniques for organic chemistry and its related content in lower secondary classes. This is why different physical pedagogical activities were prepared to teach one topic of the chemistry subject in S2 classes, the Properties of Organic Compounds, by comparing the learning outcomes and academic achievement between the activity-based teaching technique and conventional teaching techniques.

The embodiment theory, together with experiential learning theory, are guiding this research. It was found that physical actions are important to knowledge acquisition (Borghi & Caruana, 2015). In addition to this, the daily life experience of learners can be combined in the physical embodiment to maximise the gain in academic achievement. The daily human experience positively influences his or her capacity of concept understanding (Hedegaard, 1998). The learning is taking place toward the daily experience through purposive action, linked to learning objectives (Kolb et al., 2014). The following hypothesis guided the study:

- There is no significant difference between the academic achievement of S2 students taught properties of organic compounds using the activity-based teaching technique and those taught using the conventional teaching techniques.

Methodology

Research population

The total population is composed of 1610 students from ten pre-selected schools of Gasabo district to include secondary schools under the nine and twelve years basic education, both public and government-aided schools. The study was conducted in eight classes; however, data from four classes only were found to be complete. This gives two treatment classes and two comparison classes for two teachers. The analysed data are based on the four intact classes with 166 students.

Research design

This study employed the quasi-experimental design whereby treatment and comparison classes were selected per school. The treatment and comparison classes were selected randomly. The groups, treatment and comparison classes can be said equal if there is no difference between them related to the pre-test grades. The hypothesis was tested to ensure whether there was any difference in both groups from pre-test to post-test. Each chemistry teacher from the selected secondary school considered only two chemistry classes. To have one class become a treatment class and the other class become a comparison class.

In this study, for the treatment classes, the chemistry teacher applied the activity-based technique with physical pedagogical activities while teaching unit 10 of S2 chemistry subject of the Properties of Organic Compounds and Uses of Alkanes. The conventional technique was applied in teaching the same unit for the comparison class. In both classes, the pre and post-test, achievement test, was administered to all students, and they were given five minutes to respond to it. This was done before and after the unit in both classes to be able to compare the effectiveness of the activity-based teaching technique in teaching the Properties of Organic Compounds and Uses of Alkanes in S2 as compared to conventional teaching technique (Karamustafaoğlu & Mamlok-Naaman, 2015). Table 1 highlights how the study is designed.

Research instrument

The achievement test was developed to determine the students' understanding or mastering level of the selected topic in S2 of Properties of Organic Compounds and Uses of Alkanes. The questions were mainly made of multiple-choice questions. The multiple-choice achievement test tool of 6 questions was developed for both pre and post-test purposes. The five questions of it have four options each, one correct answer and three distracters. The sixth question is a matching question with two columns. The first column has both organic and inorganic compounds to be matched with their respective characteristics in the second column of ten options, five of which are for organic compounds and the other five for the inorganic compound. Questions were from the approved student's book by the Rwanda Education Board (REB) (Sandra et al., 2017). Additional reliability and validity test were not judged necessary as the tests were standardised. However, the pilot test was conducted to assess the timing and the order of questions to make it much smarter. Chemistry teachers were consulted to make a final version of the pre-test and post-test tool. The pre-test and the post-test were

Table 1 The research design

Chemistry classes	Pre-tests	Teaching techniques	Post-tests
Treatment class	Multiple-choice test	Activity-based	Multiple-choice test
Comparison class	Multiple-choice test	Conventional	Multiple-choice test

Source: Researcher, 2019

composed of the same questions, and the same duration was accorded to each class.

The lesson plan for the activity-based technique was prepared and given to chemistry teachers for its use when teaching chemistry. Before the use of the activity-based teaching technique in class, all teachers received a one-day orientation on how to use the prepared physical activities in teaching chemistry. After that, there was a possibility of using them either in the classroom or outside the classroom. The actual use of prepared pedagogical physical activities in teaching the Properties of Organic Compounds and Uses of Alkanes in S2 was done in a period of 3 weeks.

At the beginning of the unit, the teacher distributed the pre-test to all learners. Leaners were supposed to attempt the six questions by selecting appropriate answers in the given list of the proposed possible answers. The same approach was made at the end of the unit with the same tool with the same questions and the same duration. Both pre-test and post-test were distributed in both treatment and comparison classes. In between, the teacher used the developed lesson plan with activity-based technique within treatment classes only. The designed pedagogical activities were used in this case. Then in comparison classes, the teacher used his or her own teaching technique as per his or her own lesson plan. All the chosen teaching techniques were categorised under conventional teaching techniques.

Data analysis

The pre and post-test data were analysed. Both descriptive and inferential statistical tests were applied where the paired-samples *t*-test together with cohen's effect size and the independent-sample *t*-test were used. Those statistical tests were done to conclude (Daniels & Minot, 2020) on the effectiveness of two teaching techniques on students' performance in chemistry, activity-based teaching technique and conventional technique when teaching organic chemistry in S2, the properties of organic chemistry compounds and uses of alkanes.

Table 2 Tests of normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Difference Score	Comparison	.090	79	.171	.984	79	.444
	Treatment	.092	87	.065	.981	87	.235

Both the K-S (Kolmogorov-Smirnov) and S-W (Shapiro-Wilk) normality tests carried out on the data reveal insignificant results (since the *p*-values are greater than 0.5). This implies that the distribution of the paired differences is not significantly different from normal, and a paired sample t-test for each of the groups is ideal since none of the other assumptions has been violated (Table 2).

Ethical consideration

The ethical consideration and confidentiality of respondents; and their freedom to withdraw from the research process anytime during the research guided this study. From the design up to the end. The ethical approval was obtained from the University of Rwanda (UR) and the authorisation of the Gasabo district in Rwanda. The consent was also obtained at the school level from both school leaders and chemistry teachers in S2 and S2 students.

Results and Discussion

The mean scores of the comparison classes in the pretest and posttest were compared using the paired sample t-test. The results of the analysis are presented in Tables 3 and 4. The mean performance of students for post-test (M = 6.35, SD = 1.78) is higher than that of the pretest (M = 4.06, SD = 1.70) (Table 3). The increase or the gain in the performance from pre-test to post-test is significant because the *p*-value is less than 0.5 (Table 4). The effect size, which is expressed as the quotient of the mean difference by the standard deviation was observed to be 1.02 (i.e., large effect since it is greater than 0.8).

Similarly, the scores of the treatment classes in the pretest and posttest were also compared using the paired sample t-test and the results presented in Tables 5 and 6. The mean performance of students for posttest (M = 6.81, SD = 1.66) is higher than that of the pretest (M = 4.40, SD = 1.73) (Table 5). The gain in performance from pre-test to post-test is significant because the p-value is less than 0.5 (Table 6).

The mean performance of students who received the treatment in the posttest (M = 6.8, SD = 1.66) was higher than what they obtained in the pretest (M = 4.3, SD = 1.72) (see Table 5). The mean gain in performance from pre-test to post-test (-2.41) is significant [t(86) = -11.3, p < .000] (see Table 6). The effect size was observed to be 1.27 which is also large effect since it is greater than 0.8.

Table 3: Descriptive statistics of scores obtained by the comparison classes

	Mean	N	Std. Deviation	Std. Error Mean
Pretest	4.1	79	1.70	.1907
Posttest	6.3	79	1.78	.1999

Table 4: Paired samples test results of scores obtained by the comparison classes

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Dev.	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pretest-Posttest	-2.28	2.23	.25	-2.78	-1.78	-9.10	78	.000

Table 5: Descriptive statistics of scores obtained by the treatment classes

	Mean	N	Std. Deviation	Std. Error Mean
Pretest	4.4	87	1.73	.1850
Posttest	6.8	87	1.66	.1778

Table 6: Paired samples test results of scores obtained by the treatment classes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest-Posttest	-2.41	1.90	.2041	-2.82	-2.01	-11.83	86	.000

The paired samples t-test reveals that students exposed to both teaching methods (comparison and treatment classes) showed significant improvements in their performance. However, the effect size for the treatment classes outweighs that of the comparison classes. This confirms that students' performance gain was higher in the treatment classes (M = 6.81, SD = 1.66) than that of the comparison group (M = 6.35, SD = 1.78). Another study that tried to assess the effectiveness of the activity-based techniques as compared to conventional teaching for undergraduate students (Patil, et. al., 2016) obtained the same confirmation.

Results of the Independent samples t-test

Based on the descriptive statistics displayed in Tables 3 and 5, the treatment group (M = 4.40, SD = 1.73) seems to have performed better than the comparison group (M = 4.06, SD = 1.70) in the pretest. Similarly, the treatment group (M = 6.81, SD = 1.66) seems to have performed better than the comparison group (M = 6.35, SD = 1.78) in the posttest. The independent sample *t*-test was used to ascertain whether or not the differences observed are statistically significant (Noreen & Rana, 2019). The result of the test are presented in Table 7.

From Table 7, it can be seen that the mean posttest score of the treatment classes (M = 6.8, SD = 1.66) was found to be significantly higher than that of the comparison classes treatment (M=6.3; SD=1.78); [$t(163) = -1.73$, p =.085], indication the difference is not significant. The paired samples t-tests reveals that students exposed to both teaching methods (comparison and treatment classes) showed significant improvements in their performance. However, the effect size for the treatment classes outweighs that of the comparison classes. This confirms that students' performance gain was higher in the treatment classes (M = 6.81, SD = 1.66) than that of the comparison group (M = 6.35, SD = 1.78). The same confirmation was obtained by another study that tried to assess the effectiveness of the activity-based techniques as compared to conventional teaching for undergraduate students (Patil et al., 2016).

The independent sample t-test was also used on the pre-test and post-test results of the treatment and comparison classes to to ascertain whether or not the differences observed in the means are statistically significant es (Noreen & Rana, 2019). The test result are als presented in Table 7.

The test result reveals that the difference is not significant (Table 7). Based on a study conducted by Anwar (2019), the activity-based techniques were found to interest students with a positive impact on both performance and motivation as compared to conventional teaching techniques. However, results displayed in Table 9 show that these differences were not significant for both the

pretest, t(162.97) = -1.25, p = .212, and the academic achievement, in Nigeria and

Table 7 **Independent samples t-test comparing posttest scores of the treatment and comparison groups**

Group		N	Mean	Std. Dev.	Mean Diff.	t	df	Sig. (2-tailed)	95% Confidence Interval of the Difference	
									Lower	Upper
Pre-test Comparison	EVA	79	4.06	1.7	-.4622	-1.734	164	.085	-.9888	.0643
Pre-test Treatment		87	4.4	1.73						
Posttest Comparison	EVA	79	6.35	1.78	-0.333	-1.25	162	.212	-0.858	0.191
Posttest Treatment		87	6.81	1.66						

EVA → Equal variances assumed

posttest, t(164) = -1.73, p = .085.

We accept the null hypothesis. But, as far as the gain is higher in treatment classes as compared to comparison classes, there is high confidence that once teachers are supported significantly in the use of activity-based teaching techniques for an organic chemistry topic, students performance will be increased significantly. The developed physical activities involve physical embodiment. It was found that one's experience influences his or her concept understanding (Botha, 2005). The physical embodiment increases the academic outcomes in any subject (Sullivan, 2018).

Based on the positive results of the three weeks allocated to implementing physical pedagogical activities. As a new approach to them, it is an excellent start. It is found that teachers need sufficient time to be inducted well in the use of physical pedagogical activities in teaching chemistry; it needs more continuous support during the teaching. A study conducted in mathematics education reveals that activity-based teaching techniques are better than traditional teaching techniques in elementary grades (Noreen & Rana, 2019). The same benefit of the activity-based technique was observed in chemistry teaching, a greater impact on the students' Turkey (Ajayi, 2017; Duvarci, 2010; Udu & Eze, 2018). Based on positive findings from this study regarding performance gain, more orientation sessions and the on-job mentoring and coaching of teachers in using activity-based teaching techniques are recommended.

Conclusion

This study confirms the considerable benefit of using activity-based teaching techniques while teaching chemistry in the low secondary classes with limited instructional materials as compared to the conventional teaching techniques, the most preferred teaching technique by the concerned teachers. The activity-bassed teaching technique was the best. The students' performance was higher in the treatment classes (M = 6.81, SD = 1.66) than the comparison group's (M = 6.35, SD = 1.78) on the Properties of Organic Compounds topic S2 chemistry class. However, difference was not significant, t(164) = -1.73, p = .085

The combination of the embodiment theory and experiential learning theory is possible and generates a double positive effect if well utilised. Different sessions can be organised for teachers to use more physical activities linked to learners' daily experience and linked to the expected learning outcome to

maximise the benefit of using the activity-based teaching technique.

The study recommends more support to teachers in lesson preparation of the activity-based teaching techniques using physical pedagogical activities for chemistry teaching. This teaching technique is good at making chemistry class enjoyable and stimulating the students' interest. In-service teacher training can be organised to master this physical embodiment technique. The education system is encouraged to explore more on the benefits of this technique for holistic child development.

Limitation of the study

The pre-test and post-test were used in the form of formative assessment, and each test was allocated only five minutes.

The topic of properties of organic compounds is the last one in S2, and during the period we were conducting our research, teachers were busy in different activities of the end of the school year, including examination preparation and covering as much as possible the expected content before the end of the school calendar. As a result, only two teachers out of four who were involved in the study were able to complete all activities, including the post-test.

Orientation for teachers was eight hours, and implementing the activity-based teaching technique took three weeks.

Acknowledgements

ACEITLMS supported this study; school leaders, teachers, and students who were involved in this study. Thank you!

References

Ajayi, V. O. (2017). Effect of Hands-on Activity-Based Method on Interest of Senior Secondary Students in Organic Chemistry. *Scholarly Journal of Education*, *6*(1), 1–5. https://ssrn.com/abstract=2990676

Anwar, F. (2019). Activity-Based Teaching, Student Motivation and Academic Achievement. *Journal of Education and Educational Development*, *6*(1), 154–170. https://doi.org/10.22555/joeed.v6i1.1782

Ashwin, P., & Mcvitty, D. (2015). The Meanings of Student Engagement : Implications for Policies and Practices. In A. Curaj, L. Matei, R. Pricopie, J. Salmi, & P. Scott (Eds.), *The European Higher Education Area* (pp. 343–359). Springer, Cham. https://doi.org/https://doi.org/10.1007/978-3-319-20877-0_23

Borghi, A. M., & Caruana, F. (2015). Embodiment Theory. In *International Encyclopedia of the Social & Behavioral Sciences: Second Edition* (Second Edi, Vol. 7). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.56025-5

Botha, M. E. (2005). Metaphors, domains and embodiment. *Koers - Bulletin for Christian Scholarship*, *70*(3), 401–423. https://doi.org/10.4102/koers.v70i3.277

Cardellini, L. (2012). Chemistry: Why the Subject is Difficult? *Educación Química*, *23*, 305–310. https://doi.org/10.1016/s0187-893x(17)30158-1

Daniels, L., & Minot, N. (2020). An Introduction to Statistics and Data Analysis Using Stata. In *SAGE Publications*.

Duvarci, D. (2010). Activity-based chemistry teaching: A case of "elements and compounds." *Procedia - Social and Behavioral Sciences*, *2*(2), 2506–2509. https://doi.org/10.1016/j.sbspro.2010.03.362

Fonseca, J. M. B., & Conboy, J. E. (2006). Eurasia Journal of Mathematics, Science and Technology Education. *Eurasia Journal of Mathematics, Science and Technology Education*, *2*(2).

Hansraj. (2017). Activity -Based Teaching - Learning Strategy in Language. *Scholarly Research Journal for Humanity Science & English Language*, *4*, 4433–443620.

Hedegaard, M. (1998). Situated Learning and Cognition: Theoretical Learning and Cognition. *Mind, Culture & Activity*, *5*(2), 135–142. https://doi.org/10.1207/s15327884mca0502

Karamustafaoğlu, S., & Mamlok-Naaman, R. (2015). Understanding electrochemistry concepts using the predict-observe-explain strategy. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(5), 923–936. https://doi.org/10.12973/eurasia.2015.1364a

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2014). Experiential learning theory: Previous research and new directions. *Perspectives on Thinking, Learning, and Cognitive Styles*, *216*, 227–247. https://doi.org/10.4324/9781410605986-9

Noreen, R., & Rana, A. M. K. (2019). Activity-Based Teaching versus Traditional Method of Teaching in Mathematics at Elementary Level. *Bulletin of Education and Research*, *41*(2), 145–159.

Ogunkola, B. J., & Samuel, D. (2011). Science Teachers ' and Students ' Perceived Difficult Topics in the Integrated Science Curriculum of Lower Secondary Schools in Barbados Science Teachers ' and Students ' Perceived Difficult Topics in the Integrated Science Curriculum of Lower Secondary S. *World Journal of Education*, *1*(October). https://doi.org/10.5430/wje.v1n2p17

Patil, U., Budihal, S. V., Siddamal, S. V., & Mudenagudi, U. K. (2016). Activity Based Teaching Learning: An Experience. *Journal of Engineering Education Transformations*, *0*(0). https://doi.org/10.16920/jeet/2016/v0i0/85433

Sandra, M., Ndekezi, M., Grissell, T., & Kemp, E. (2017). *Comprehensive Chemistry for Rwanda Schools: Student's Book—Secondary 2* (Issue i). Laxmi Publications (P) Ltd. https://reb.rw/fileadmin/SCIENCE_E_BOOKS/E_BOOKS/Chemistry/Chemistry S2/Chemistry S2 SB Final 5-05-2017.pdf

Sesmiyanti, S. (2016). Student ' s Cognitive Engagement in Learning Process. *Journal Polingua : Scientific Journal of Linguistics, Literature and Education*, *5*(2), 48–51. https://doi.org/https://doi.org/10.30630/polingua.v5i2.34

Sullivan, J. V. (2018). Learning and Embodied Cognition: A Review and Proposal. *Psychology Learning and Teaching*, *17*(2), 128–143. https://doi.org/10.1177/1475725717752550

Treagust, D., Duit, R., & Nieswandt, M. (2000). Sources of students ' difficulties in learning Chemistry. *Educación Química*, *11*(2), 228–235. https://doi.org/http://dx.doi.org/10.22201/fq.18708404e.2000.2.66458

Uchegbu, R. I., Oguoma, C. C., Elenwoke, U. E., & Ogbuagu, O. E. (2016). Perception of Difficult Topics in Chemistry Curriculum by Senior Secondary School (II) Students in Imo State. *AASCIT Journal of Education*, *2*(3), 18–23.

http://www.aascit.org/journal/education

Udu, D. A., & Eze, C. U. (2018). Utilisation of learning activity package in the classroom: impact on senior secondary school students' achievement in organic chemistry. *African Journal of Chemical Education*, *8*(2), 49–92.

Woldeamanuel, M. M., Atagana, H., & Engida, T. (2014). What makes chemistry difficult? *African Journal of Chemical Education*, *4*(2), 31-43–43.