



Effect of Problem-Based Learning on Secondary School Students' Engagement in Chemistry in Onitsha Education Zone

Pius P. Obinna & Okoli Josephine N.

Department of Science Education, Nnamdi Azikiwe University, Awka

Corresponding Author: Promisepius850@gmail.com

Abstract

The study determined the effect of problem-based learning on secondary school students' engagement in chemistry in Onitsha Education Zone. Two research questions and three hypotheses guided the study. Quasi-experimental design was used. The population of the study was 1, 821 SS2 students offering chemistry in Onitsha Education Zone. The sample size was 144. The instruments used are Students Engagement Questionnaire (SEQ) validated by three experts. Cronbach Alpha reliability of SEQ was 0.77. Mean and standard deviation and analysis of covariance was used for data analysis. The findings PBL significantly improved achievement in chemistry more than conventional method. It was concluded that PBL is effective for making students to be seriously engaged in the learning process of chemistry. It was recommended among others that chemistry teachers should always adopt the use of PBL to ensure greater engagement of students in the learning process while improving their cognitive, emotional and behavioral engagements.

Keywords: Problem-Based Learning, Engagement, Chemistry, Titration, Acid

Introduction

Education as a process requires that students must be actively engaged in the learning process if meaningful learning must occur. Cognitive engagement could help the students to develop cognitive skills, emotional engagement develops the affective domain while behavioural engagement enhances psychomotor skills. The effect of learning when students are actively engaged is therefore said to be whole and results in students acquiring the necessary skills needed in science education. Instructional methods, therefore, are learner-centred which and facilitate students' engagement in the learning process are known to be important for improved learning.

Students' engagement according to Al-Munnir, Yunusa and Jacob (2018) is generally used to describe meaningful student involvement throughout the learning environment. Students can be engaged cognitively, emotionally, and behaviourally (Kuh, 2009). Cognitive engagement is the psychological state in which students put in a lot of effort to truly understand a topic and in which students persist studying over a long period of time. It has traditionally been operationalized by measuring the extent of students' homework completion, class attendance, extra-curricular participation in activities, or their general interactions with the teachers, and how motivated they seem while engaging in classroom discussions. Behavioural engagement is the students'

participation and effort in class while emotional engagement is the students' interest and feeling towards what is happening in the classroom. Each of these types of engagement, according to Witkowski (2015) plays a role in students' learning processes. The method adopted by the teacher is one of the important factors that determine the students' level of engagement.

Some authors Fernandes, Mesquita, Flores and Lima (2014); Robinson (2013) suggest that engagement is more or less dependent on the task at hand because the task determines the extent of students' autonomy. For instance, working with groups and engaging in discussions, searching for information on the internet, or listening to a lecture is likely to result in different levels of cognitive engagement because of different levels of autonomy. When students independently search for information or solve a problem, the level of autonomy is relatively high and thus leads to more engagement. Working in groups and engaging in discussions could result in either high or low feelings of autonomy, depending on the group dynamics. Thus, such strategies as problem-based learning could enhance students' engagement and facilitate the acquisition of science process skills, a result not common with the conventional teaching method.

The convention method is simply the method of instruction adopted by the teacher. It is commonly known to be teacher-centred and often involves an



expository or lecture approach of instruction. In using the conventional method, students are not given an active role in the learning process instead they are passive. The use of the convention method is a common choice for teachers because it enables them to cover large content areas and teach a large number of students. However, it is not known to be the potential common in most innovative teaching methods such as problem-based learning that gives students an opportunity to take responsibility for their learning.

Problem-based learning (PBL) is an educational approach in which complex problems serve as the context and the stimulus for learning (Eze, Ezenwafor & Obidile, 2016). In PBL classes, students work in teams to solve one or more complex and compelling 'real world' problems. The instructor in a PBL class facilitates the learning process by monitoring the progress of the learners and asking questions to move the students forward in the learning process, the instructor is not the sole resource for content or process information, but instead guides students as they search out appropriate resources (Caesar, Jawawi, Matzin, Shahrill, Jaidin & Mundia, 2016).

In the problem-solving classroom, the teachers use the following steps during instruction: Begin with a task embedded in a familiar setting; introduce problem-solving techniques that might be applicable, allow students to create their paths to a solution, emphasize collaborative learning and problem solving, help develop collaborative working skills, provide different roles for individuals in a group setting and identify, confront and discuss misconceptions.

The concept of the PBL method is the result of other learning theories such as Kolb's Theory which emphasizes experience-based learning; Piaget's Theory, Vygotsky, Lave, and Wenger, which focus on constructivism; social learning and Schon theory which concentrates on the reflection process. PBL according to Duda, Susilo and Newcombe (2019) can be interpreted as a form of cognitive-constructivist learning, based on at least three assumptions.

The first assumption is that in PBL students engage in theory construction. With the help of their peers, they develop an initial theory about the phenomena described in the problem. Subsequently, self-directed learning activities (e.g. reading books or consulting internet resources) Munoz-Campos (2017) noted serve to test the initial theory against the literature thereby elaborating, changing, and deepening their understanding of the topic. The second

assumption according to Nurzman (2017) is that the use of authentic problems or real-life problems encourages students to become interested in the topic at hand and as a consequence helps them gain a deeper understanding of the principles or processes underlying the problem. The third assumption Li and Tsai (2017) explained is that being in the position to identify one's own learning goals in collaboration with peers fosters a feeling of autonomy, agency, and empowerment. Being autonomous from the direct intervention of a teacher and feel in charge of one's learning is supposed to result in increased cognitive engagement with the topic to be learned, which eventually encourages a deeper understanding of it. As students learn through problem-based based learning they become more engaged and could acquire for themselves the necessary process skills required for science learning irrespective of gender.

The influence of gender on achievement has remained one of the most inconclusive study areas, with some studies showing that males achieve higher in Chemistry when multimedia instruction is used (Nwanze, 2016) than females while others (Emerhiona, Ajaja, Pius, Nwanze, and Izuegbuna, 2018) stated otherwise when problem and discovery-based learning methods are used. Other studies show no significant difference in achievement in chemistry when animated-media instructional strategy, cooperative and individualized instruction, and social media integrated learning and group study were used (Pius, 2018; Izuegbunam, 2018; Konyefa & Okigbo, 2021). Little however is known about the gender differences among students in terms of learning engagement. The investigation of the gender differences in learning engagement by chemistry students is, therefore, a worthwhile venture.

Purpose of Study

The purpose of the study was to determine the effect of problem-based learning on secondary school students' engagement in chemistry. Specifically, the study determined the:

1. difference in the mean engagement scores of students taught chemistry using problem-based learning (PBL) and those taught using the conventional method.
2. difference in the mean engagement scores of male and female students in chemistry taught using PBL and CM.
3. interaction effect of teaching methods and gender on students' engagement.



Research Questions

1. What is the difference in mean engagement scores of students taught chemistry using problem-based learning (PBL) and those taught using the conventional method (CM)?
2. What is the difference in the mean engagement scores of male and female students taught chemistry using PBL and CM?

Hypotheses

1. There is no significant difference between the pretest and posttest mean engagement scores of students taught chemistry using problem-based learning (PBL) and those taught using the conventional method (CM).
2. There is no difference in the mean engagement scores of male and female students taught chemistry using PBL and CM.
3. There is no interaction effect of teaching strategies and gender on students' engagement.

Method

The design adopted for the study is quasi-experimental, specifically, the pre-test, post-test, non-randomized control group design. The study was carried out in Onitsha Education Zone of Anambra State. The population of the study is 1,821 senior secondary year two (SS2) students offering chemistry in the 32 public secondary schools in Onitsha Education Zone of Anambra State. The sample of the study comprises 144 senior secondary year two (SS2) students offering chemistry in Onitsha Education Zone. The sampling technique involved a two-stage sampling procedure. The purposive sampling technique was used to select two coeducational schools from 32 secondary schools in Onitsha Education Zone. The choice of the two schools is because they have functional laboratories that are well equipped and are situated miles apart to avoid subject interaction. The two selected schools were randomly assigned to experimental and control groups (through a toss of a coin). In each of the two schools selected, all SS2 students offering chemistry were used. The experimental group comprised 82 (49 males and 33 females) students while the control group comprised 62 (38 males and 24 females) students.

The instrument for data collection was Students' Engagement Questionnaire (SEQ). Students Engagement Questionnaire (SEQ) is a 27-item scale adapted from Maroco, Campos and Fredrick (2016). The questionnaire was originally a 32-item

questionnaire designed on a scale of 1-5 from 'never' to 'always'. The instrument was however modified by removing five items that do not suit the level of students for the present study. Some of the statements were restructured and some words like professor, coursework, and colleague were replaced with teacher, subject and classmates respectively. The biographic part of the questionnaire was removed apart from gender. Also, a lesson plan on problem-based learning using the chemistry concept of mass and volume relationship and volumetric and qualitative analysis was developed. Lesson plans were also developed for the control group using the conventional method and involving the same concepts.

The instrument was validated by experts from the Department of Science Education and Educational Foundations (Measurement and Evaluation), Nnamdi Azikiwe University, Awka. The reliability of SEQ was established using the Cronbach alpha technique. Cronbach alpha was used because the items are polytomously scored that is, it has multiple ratings. SEQ was therefore given to the same 40 students in a school that will not be involved in the study. The generated scores were collated and used to compute the reliability coefficient of SEQ. The reliability coefficient obtained for SEQ is 0.77.

The experiment was conducted in two phases. The first phase involved the training of the two research assistants who are the regular chemistry teachers in the schools that were involved in the study. Students in the PBL group were taught the concept of mass and volume relationship and qualitative analysis by presenting problems for them to solve. The teacher assigned the students to a five-member group. Each problem was solved as a group and thereafter presented by only one member of the group while all members participated in answering the questions relating to the group presentation. The teacher constituted groups of five students for the lessons. To do this, the teacher assigned students a number between 1-5. For the first and second weeks, all the students bearing the number 1 formed one group while those bearing the number 2 formed one group, so also, those bearing the numbers, 3, 4 and 5. From the third week, students bearing numbers 1,2,3,4, and 5 constituted a group throughout the class. The steps to the use of problem-based learning in the classroom involved the teacher introducing the concept, explaining the concept, and solving related questions. The teacher further presents students with questions to solve in their groups. The lesson proceeded with the



teacher explaining further with other examples and giving students related questions to solve. At the end of the lesson, the teacher summarized the important points in the lesson. The control group received treatment using the same concepts but with no problems given to the students to solve. The teacher used the conventional method. Pretest was given to the students before treatment and posttest after treatment to collect data for the study.

The research questions were answered using mean and standard deviation while establishing the differences in the mean. The hypotheses were tested at 0.05 alpha level using Analysis of covariance (ANCOVA). ANCOVA was used to take care of the initial group difference among and between groups. The Decision rule was that when the probability value (p-value) is less than 0.05 or equals 0.05 ($p \leq 0.05$), the null hypothesis was rejected; otherwise, the null hypothesis was accepted.

Results

Table 1: Pretest and Posttest Mean Engagement Scores of Students taught Chemistry using PBL and CM

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gained Mean
PBL	82	66.99	7.25	118.54	10.71	51.55
CM	62	65.23	8.63	109.40	8.62	44.17
Difference		1.76		9.14		7.38

Table 1 reveals that the students taught chemistry using PBL had a pretest mean engagement score of 66.99 and posttest mean engagement of 118.54 with gained mean engagement score of 51.55, while those in the control group taught with CM had a pretest mean engagement score of 65.23 and posttest mean

engagement score of 109.40 with gained mean engagement scores of 44.17. The students in the control group had a more homogeneous score than those in the experimental group. The difference between the mean gained engagement scores of the students is 7.38 in favour of PBL.

Table 2: Pretest and Posttest Mean Engagement Scores of Male and Female Students taught Chemistry using PBL and CM

methods	Gender	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gained Mean
PBL	Male	49	68.22	6.256	118.20	10.087	49.98
	Female	33	65.15	8.269	119.03	11.725	53.88
	Difference		3.07		0.83		3.90
CM	Male	38	67.45	6.872	108.03	8.231	40.58
	Female	24	61.71	10.024	111.58	8.939	49.87
	Difference		5.74		3.55		9.29

Table 2 reveals that the male students taught chemistry using PBL has pretest mean engagement score of 68.22 and posttest mean engagement score of 118.20 with a gain in mean scores of 49.98 while the female students have pretest mean posttest score of 65.15 and posttest mean engagement score of 119.03 with a gain in mean scores of 53.88. The difference in mean engagement scores of the male and female students is 3.90 with female students having higher engagement scores than the male students. Table 5 also reveals that

the male students taught chemistry using CM has pretest mean engagement score of 67.45 and posttest mean engagement score of 108.03 with a gain in mean scores of 40.58 while the female students have pretest mean posttest score of 61.71 and posttest mean engagement score of 111.58 with a gain in mean scores of 49.87. The difference in gained mean engagement scores of the male and female students is 9.29 with female students having higher engagement scores than the male students.

Table 3: ANCOVA Test of Significance of Difference between the Mean Engagement Scores of Students taught Chemistry using PBL and CM

Source	SS	df	Mean Square	F	Sig.	Decision
Corrected Model	3298.327 ^a	4	824.582	8.506	.000	
Intercept	20581.138	1	20581.138	212.317	.000	
Pretest	153.625	1	153.625	1.585	.210	
Method	2403.199	1	2403.199	24.792	.000	Sig.
Gender	244.079	1	244.079	2.518	.115	Not Sig.
Method * Gender	80.237	1	80.237	.828	.365	Not Sig.
Error	13474.111	139	96.936			
Total	1908085.000	144				
Corrected Total	16772.438	143				

Table 3 shows that there is a significant main effect of the treatment on students’ engagement in chemistry $F(1, 139) = 24.792, p = 0.000 < 0.05$. Therefore, the null hypothesis was rejected meaning that there is a significant difference between the pretest and posttest mean engagement scores of students taught chemistry using problem-based learning (PBL) and those taught using the conventional method (CM) in favour of PBL. Table 3 also shows that there is no significant main influence of gender on students’ engagement in chemistry $F(1, 139) = 2.518, p = 0.115$. Therefore, the null hypothesis was not rejected meaning that there is no difference between the pretest and posttest mean engagement scores of male and female students taught chemistry using PBL and CM.

Table 3 further shows that there is no interaction effect of teaching methods and gender on students’ engagement in chemistry $F(1, 139) = 0.828, p = 0.365$. Therefore, the null hypothesis was rejected meaning that there is no interaction effect of teaching strategies and gender on students’ engagement.

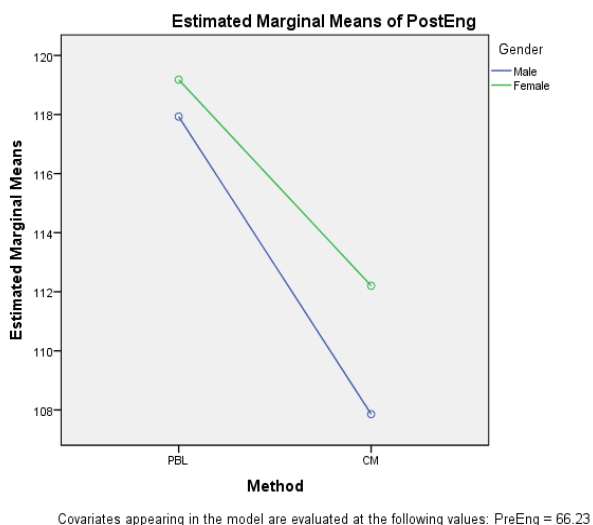


Figure 1: Plot of the interaction effect of teaching methods and gender on students’ engagement in chemistry

The plot of the interaction effect of teaching method and gender on students’ engagement in chemistry is not significant and ordinal

Discussion

The finding of the study also showed that students taught chemistry using PBL had a significantly higher mean engagement score than those taught using the conventional method. The nature of PBL ensures active engagement of students through increased attention and focus to a problem solution in order to promote meaningful learning. Thus, students participate in the learning process fully engaged instead of sitting and listening like in the case of the conventional method of instruction. In PBL, students’ engagement and active participation can be achieved through, brief question-and-answer sessions, discussion integrated into the lecture, impromptu writing assignments, hands-on activities, and experiential learning events such as conducting experiments.

PBL activates students’ cognitive engagement. This is because instructors of PBL courses need to identify what knowledge and skills students will need prior to starting problem-based learning and then build in some embedded instruction that will allow the students to gain these prerequisites. Efforts to link previous knowledge in the understanding of solutions to problems require serious cognitive effort. Providing a problem-based learning challenge can then engage students by acting as a break from normal lessons and common exercises. Their emotional engagement may also be woken as students express excitement at the gaining of new knowledge and discovering solutions to other similar



ones themselves. The manipulations and use of skills in doing the experimental work improve behavioural engagement. It is not hard to see the potential for engagement, as students collaborate to solve real-world problems that directly affect or heavily interest them.

The finding of the study supports the findings of Jerome and Henks (2011) that students' cognitive engagement significantly increased as a function of the learning event using PBL. The finding of the study is in line with the findings of Sydney (2020) that students' emotional, behavioural engagement increased significantly. The findings of the study are not in line with the findings of Cynthia and Shannon (2013) there was no indication that the use of PBL affected students' emotional engagement.

The findings of the study showed that there was no significant influence of gender on students' engagement. Also, no significant interaction effect of teaching methods and gender was observed on students' engagement. The plot of the interaction effect of teaching method and gender on students' engagement in chemistry is ordinal.

Conclusion

The conclusion that can be drawn from the finding of the study is that the use of PBL in teaching chemistry is effective for improving students' learning engagement.

Recommendations

1. Chemistry teachers should structure real-world problems and give them to students to solve via experimental verifications to help them master and improve science process skills.
2. Chemistry teachers should always adopt the use of PBL to ensure greater engagement of students in the learning process while improving their cognitive, emotional, and behavioural engagements.

References

Al-Munnr, A., Yunusa, A. and Jacob, D. (2018). Students' engagement in relationship to academic performance *Journal of Education and Social Sciences*, 8(1), 14-21.

Caesar, M. I. M., Jawawi, R., Matzin, R., Shahrill, M., Jaidin, J. H. and Mundia, L. (2016). The benefits of adopting a problem-based learning approach on students' learning developments

in secondary geography lessons. *International Education Studies*, 9, 51-65.

- Duda, H. J., Susilo, H. and Newcombe, P. (2019). Enhancing different ethnicity science process skills: problem-based learning through practicum and authentic assessment. *International Journal of Instruction*, 12, 1207-1222.
- Emerhiona, F., Ajaja, O.P., Pius, P. O., Nwanze, A. C. and Izuegbuna, A. G. (2018). Effects of problem and discovery-based instructional strategies on students' academic achievement in chemistry. *International Journal of Innovative Research and Advanced Studies (IJIRAS)*, 5(6), 209-214.
- Eze T. I, Ezenwafor J. I. and Obidile I. J. (2016). Effects of problem-based teaching method on students' academic performance and retention in financial accounting in technical colleges in Anambra State. *Scholars Journal of Arts, Humanities and Social Science*, 4(6A), 634-639.
- Fernandes, S., Mesquita, D., Flores, M. and Lima, R. M. (2014). Engaging students in learning: findings from a study of project-led education. *European Journal of Engineering Education*, 39(1), 55-67.
- Izuegbunam, A. G. (2018). *Effect of cooperative and individualized instruction on students' achievement in chemistry in Awka south local government area*. Unpublished Master's thesis submitted to Nnamdi Azikiwe University, Awka.
- Konyefa, B.I. & Okigbo, E.C. (2021). Effect of ethnochemistry instructional approach on secondary school students' achievement in chemistry in Bayelsa state. *International Journal of Education and Evaluation*, 7(5), 1-11.
- Kuh, G. D. (2009). The national survey of student engagement: Conceptual and empirical foundations. *New Directions for Institutional Research*, 2009(141), 5-20.
- Li, H. C. and Tsai, T. L. (2017). The implementation of problem-based learning in a Taiwanese primary mathematics classroom: lessons learned from the students' side of the story. *Educational Studies*, 43, 354-369.
- Munoz-Campos, D. (2017). Problem-based learning: an experiential strategy for english language teacher education in Chile. *PROFILE Issues in*



Teachers' Professional Development, 19, 29-40.

Nurzaman, G. (2017). The use of problem-based learning model to improve performance in the laboratory. *Analytical and Bioanalytical Chemistry, 405(1), 7-13.*

Nwanze, A.C. (2016). *Effect of multimedia synchronized instructional strategy on students' achievement and retention in secondary school chemistry in Onitsha Education Zone.* Unpublished Master's thesis submitted to Nnamdi Azikiwe University, Awka.

Pius, P.O. (2018). *Effects of animated-media instructional strategy on achievement, interest and retention in chemistry by students in Awka Education Zone.* Unpublished Master's thesis submitted to Nnamdi Azikiwe University, Awka.

Robinson, J. (2013). Project-based learning: improving student engagement and quality learning students morals. *Journal of Education and Practice, 8, 234-248.*

Witkowski, C. (2015) An Investigation into student engagement in higher education classrooms. *InSight: A Journal of Scholarly Teaching, 10, 56-67.*