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Effect of Problem-Based Learning on Developing Science Process Skills and Learning Achievement on the topic of Safety in Our Environment

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ABSTRACT
This study aimed to examine the effect of problem-based learning (PBL) in developing science process skills (SPS) and learning achievement on the topic of *'Safety in Our Environment'* in secondary schools in Tanzania. The study employed a quasi-experimental design. The participants for the study were Form One 'Stream E' students in the experimental school and Form One 'Stream D' students in the control school. Data were collected using a structured questionnaire and an achievement test. The results showed that the use of the PBL approach increased the mean scores from pre-test to post-test that were statistically significant at p = .00 in developing SPS compared to traditional teaching methods. Also, the use of PBL showed an increase in students' scores on the achievement test compared to the traditional teaching methods. Traditional teaching methods have the ability to retain achievement at a low level of cognitive ability as compared to PBL. Furthermore, PBL showed that there was no statistically significant difference in achievement based on gender as compared to the traditional teaching methods. The study recommends a continuous use of learner-centered approaches such as PBL in teaching and learning science subjects including Biology

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Introduction

Contemporary developments in science and technology have necessitated changing instructional approaches in teaching and learning science in secondary schools for developing learners' skills that would make them competitive in the 21st century (Ozgelen, 2012). These advancements have triggered different countries to change their curriculum in order to address skills that will enable them in solving problems and become contributing members of society (Nzima, 2016; Omiko, 2015). For the students to solve problems in the future life, they need to acquire the six fundamental basic Science Process Skills (SPS) at the early stages of their education.

Science process skills are the thinking skills that are used by scientists during the construction of knowledge toward solving problems (Mutlu & Temiz, 2013; Ozgelen, 2012). Science process skills are of two categories, namely, basic SPS and integrated SPS (Aydoğdu, 2015). While integrated SPS are complex and therefore used in higher grade students, basic SPS are simple skills that are essential for

foundational cognitive functioning in students at lower levels, such as ordinary level students in Tanzania (Athuman, 2017). SPS are very important and are a part and parcel of the everyday life of an individual. They are used in the construction of knowledge during learning science subjects, and hence are helpful to students in understanding scientific concepts (Aydın, 2013). Moreover, SPS are useful in conducting scientific investigations, generating results, and solving problems in daily life (Mutlu & Temiz, 2013). As such, SPS are very important to students, scientists, and everybody's life (Kazeni, 2005). There are six important SPS that are used in learning science, especially at the lower level of education. These are observation, communication, classification, measurement, inference, and prediction (Athuman, 2017; Yadav & Mishra, 2013). Developing SPS of students is pivotal in science education provision worldwide. Many countries have adopted education systems aiming at developing SPS such as the United Kingdom and the United States (Omiko, 2015), South Africa (Ambross, 2011), as well as Kenya (Mutisya et al., 2014). Studies have shown that the development of SPS requires learning approaches that promote their development. Problem-based Learning (PBL) as among the learner-centred approaches lacks more information on its ability in developing SPS and learning achievement (Athuman, 2017; Rabacal, 2016).

PBL is a learner-centered approach that facilitates learning by using the problem as a starting point for learning (Bokonjic et al., 2009). It is believed to be a powerful and effective approach compared to traditional teaching approaches in engaging students in their learning (Balım et al., 2016; Wu et al., 2020). PBL approach requires teachers to assume responsibility for facilitating students' acquisition of skills for survival in today's world by insisting on collaborative learning, critical thinking, and problem-solving skills (Msonde, 2011). According to the PBL approach, students work together and structure their own ways of getting knowledge through inquiring, searching, and solving problems (Balım et al., 2016).

The PBL approach was at first used in the field of medicine where a problem was the triggering motivator for students' learning (Baumgartner & Zabin, 2008; Barrows & Tamblyn, 1980; Rahayu et al., 2019). After showing promising results in developing various skills in students like creativity, problem-solving, self-directed learning, and science processes, PBL was then adopted in other fields including education (Balım et al., 2016; Gomoll et al., 2020; Hung, 2016). Studies that have compared PBL with traditional approaches to teaching offer factual insights into the relative value of the PBL approach as a means of reaching student mastery of curricular content (Hidayat et al., 2020; Zhao et al., 2020). These comparative studies revealed that PBL is an effective means of teaching content knowledge. For instance, the use of PBL had a positive impact on learning the mixtures topic in a Chemistry classroom as compared to the traditional approaches (Üce & Ateş, 2016). According to Tarhan et al. (2008), the use of PBL was more helpful in removing students' misconceptions of the intermolecular concepts in teaching and learning chemistry than the traditional teaching approaches. Studies that compared inquiry-based learning approaches such as PBL and traditional teaching methods on students' achievement revealed that inquiry-based learning approaches were better than traditional teaching methods. The studies by Tawfik et al. (2020) and Iswari et al. (2018) showed that the use of PBL as one of the inquiry-based learning approaches outperformed the traditional teaching methods and case-based learning in conceptual understanding. Despite its significance, PBL has been criticized for providing minimal guidance leading to a cognitive burden for learners (Kirschner et al., 2006). For PBL to be effective, seven steps must be followed in classroom instructional activities (Bokonjic et al., 2009). These are *clarifying terms, defining the problem*, *brainstorming*, *structuring and hypothesis*, *stating learning objectives*, *searching for information* and synthesis.

In Tanzania, PBL has been articulated to be one of the most learner-centered approaches that have been indicated in the competence-based curriculum (CBC) for developing SPS (MoEVT, 2005). In this context, various studies have been conducted to find out the learning of sciences subjects including Biology. Studies conducted by Kasuga (2016) and Athuman (2017) on teaching and learning approaches used in teaching and learning Biology revealed that the predominant teaching and learning methods used by teachers were traditional and teacher-centered. Teachers failed to promote student-centered learning procedures such as observations, generation and testing of hypotheses

through experimentation, and discussion of findings from observations and experiments. A study by Mkomele (2015) revealed that the use of teacher-centered approaches hindered students from the acquisition of critical thinking skills in Biology subjects. This led to students graduating with minimal thinking skills and problem-solving skills (Kafanabo, 2006; Mkomele, 2015) as such traditional approaches do not promote the development of SPS. A study by Maro (2013) showed that students and teachers were satisfied with the use of a learner-centered approach using activity-based learning.

The learning of science subjects including Biology that aim at developing SPS requires an appropriate approach that is well understood by teachers and students. For example, the Biology syllabus directs teachers to involve students in making observations during Biology learning through conducting field studies (MoEVT, 2005). Also, it directs teachers to guide students to observe the major features of the environment found in the school surroundings and record observations in exercise books (MoEVT, 2005). These skills are possibly developed by adopting learner-centered approaches such as PBL rather than using teacher-centered approaches. As the literature indicates approaches that are used by teachers in teaching science subjects including Biology have little contribution to developing SPS (Hussain & Alhtar, 2013). This may hinder the goal of the nation towards industrialization that requires individuals who are well equipped with scientific skills that are necessary in the current world. PBL as one of the suggested learner-centered approaches for teaching science subjects including Biology has little information in Tanzania. This raised interest for the researchers to conduct the study to investigate the effect of PBL on developing SPS in teaching and learning Biology subjects in secondary schools on the topic of *'Safety in Our Environment* 'for Form ones students. The topic was selected purposefully as it contains subtopics that have real-life problems that require PBL in order to solve them in the context of their learning environment (MoEVT, 2005).

Maintaining safety in our environment has become a topical issue, especially in the current century where there is a cry for climatic changes taking place in the world. Some of the notable problems associated with poor waste disposal are the effect on human health such as skin irritation, blood infections, respiratory problems, growth problems, and reproductive issues. Poor waste disposal has been affecting animals in terrestrial and marine life by eating affected grasses near contaminated areas (Anup, 2015) Also poor waste disposal is said to cause extreme climatic changes, soil contamination, air contamination, and water contamination (Shaftel, 2013). Based on these problems associated with poor waste disposal, the curriculum of Tanzania included the topic of "Safety in Our Environment" to be taught to Form I students, in which various ways of waste disposal are taught (MoEVT, 2005). The major problem in this topic is that students have been performing poorly. In National examinations, for example, students have shown poor performance on the topic of Safety in Our Environment for many years. The items analysis report for the Certificate of Secondary Education Examination of 2019 shows that, students scored poorly on the question on the topic of Safety in Our Environment. In this question, the candidates were instructed to briefly explain three problems that are likely to happen to the communities which pollute their water source by disposing of the wastes. The results show that out of 423,842 candidates who responded to the question, 37.8 percent scored from 0 to 1.5 marks, out of which, 29 percent scored a 0 mark. The candidates who scored from 2 to 3.5 marks were 30.8 percent whereas 31.4 percent scored from 4 to 6 marks. (URT, 2020) The factors for poor achievement in this topic include the methods used to deliver the content on the topic that does not promote the development of SPS (Athuman, 2017). Studies have indicated that the traditional methods used, cannot instill in students problem-solving skills Athuman, 2017; Mkomele, 2015). The use of learner-centered approaches such as activity-based learning has indicated an added value for the students in learning Biology and other science subjects in Tanzania (Maro, 2013; Mbwile, 2020).

Aim

This study aimed to examine the effect of PBL in developing SPS and learning achievement of secondary school students on the topic of Safety in Our Environment. The study sought answers to the following questions.

i. Is there a significant difference in mean scores between students who were taught using PBL and those who were taught using traditional methods in developing SPS on the topic of Safety in Our Environment?
ii. Is there a significant difference in mean scores between students who were taught using PBL and those who were taught using traditional methods in achievement test on the topic of Safety in Our Environment?
iii. Is there a gender difference in mean scores between pre-test and post-test in the achievement test for students who were taught using PBL and those who were taught using traditional methods on the topic of Safety in Our Environment?

Methods

Participants

The respondents for this study were the Form One students in the experimental school and control school from the Njombe region, Tanzania. In the experimental school, Form One 'E' stream (n = 38) was selected purposefully as it was the stream with a fewer number of students while in the control school Form One 'D' stream (n = 42) was selected with a fewer number of students. The small number of students per stream necessitated implementing PBL.

Design and Data Collection Tools

The study employed a quasi-experimental design using non-equivalent group designs (pre-after with control design) (Cohen et al., 2018). Data were collected using a questionnaire and an achievement test. The achievement test consisted of 17 items with multiple choice questions, short answers, and an essay question. The questions intended to measure various cognitive skills as suggested by the revised Bloom Taxonomy, whereby 5 test items measured remembering, 3 items were for understanding, 3 items for applying, 2 items for analyzing, 2 items for evaluating, and 2 items for creating (see appendix A). Content validity was ensured by using the biology syllabus in constructing the test items. To test the reliability of the question items, a pilot study was conducted prior to the administration of the test to the intended group of students. Using a split-half method, the correlation coefficient (r) of the half-test was computed and then the correlation for the full test (r_2) was computed using the formula:

$$r_2 = \frac{2r}{r+1}$$

Where r_2 is the correlation of the full test, r is the correlation of the half-test. It was found that the correlation coefficient (r_2) for the full test was 0.84 obtained after the coefficient of the half-test of 0.72. Before the implementation of PBL, a pre-test was administered to Form One 'E' in the experimental school and Form One 'D' in the control school. The major aim for the pre-test was to measure the achievement of the students before being exposed to the PBL for experimental school and traditional methods to control school. After the implementation which took eight weeks, a post-test was administered to the same students in the experimental school and control school. The post-test paper consisted of the same items as those used during the pre-test but differed in arrangement for the short answer items and multiple-choice items.

Also, this study used a structured questionnaire that intended to get the responses from the students before and after the implementation. A structured questionnaire prescribes the range of responses from which the respondent may choose. This type of questionnaire is useful in that it can generate frequencies of response amenable to statistical treatment and analysis (Cohen et al., 2018). It also enables comparisons to be made across groups in the sample. Its major advantage is that data generated from the questionnaire are quicker to code and do analysis. The questionnaire was

constructed by the researchers with the help of ideas of Bokonjic et al. (2009). The questionnaire used a Likert scale with five points that ranged from 1 = strongly disagree to 5 = strongly agree. The Cronbach Alpha was used to calculate the reliability of the questionnaire items for each category. The Cronbach Alpha values for subcategories are presented in Table 1.

Table 1

Reliability of the Questionnaire Items (N=80)

	Cronbach Alpha
Science Process Skills	α- values
Observation skills (5 items)	.73
Communication skills (6 items)	.64
Classification skills (4 items)	.71
Measurement skills (4 items)	.70
Prediction skills (5 items)	.73
Inference skills (5 items)	.68

Implementation of PBL in Experimental School

The implementation of PBL included the teaching materials with seven stages as proposed by Bokonjic et al. (2009). A brief summary of the steps used during implementation is shown in Table 2.

Table 2

Steps of Problem-based Learning used in the Study

Stages	Activities
Clarifying terms	_First, the students draw a table on the board in the classroom, consisting of four columns: Facts in the text, Problem, Hypotheses about cause and effect, and Learning objectives. The text with the problem to be identified and solved is then introduced to the students, and unknown terminology is explained and clarified. After this, the facts presented in the text are listed in the "facts in the text" column on the board.
Defining the problem	_The second step consists of group discussions of what the problem is and which methods can be used to find the solution. The identified problem is then written down in the "problem" column on the board.
Brainstorming	_Another group discussion is held where the students use their prior knowledge to come up with ideas for different hypotheses to explain the problem. During this step, all students are encouraged to speak their minds and all ideas are valued and noted.
Hypothesis	_A review of steps two and three is carried out and different possible explanations of the problem are given, eventually leading up to one final structured hypothesis, which is then written down in the "hypotheses about cause and effect" column.
Learning objectives	_When the hypothesis is chosen and formulated the students must agree on achievable and comprehensible learning objectives for the task. These objectives will be the necessary knowledge the students need to acquire before they will be able to continue working with their hypothesis. These learning objectives are written down in the "Learning objectives" column on the board.
Searching for	_The search for information is done individually and with emphasis on mutual learning objectives. This will provide the students with more

information	profound knowledge regarding the problem they are working on.
Synthesis	_During this step, the members of the group share the results of their individual findings with each other. With this new information they analyze the stated problem and, hopefully, they come to an understanding of, and solution to the identified problem.

Reduction of threats to internal validity

In order to avoid the threats to internal validity, the researchers dealt with issues of history, maturation, mortality, testing, instrumentation, and design contamination as explained briefly in the following section. Students in the experimental school and control school were taught using the same syllabus. The National Examination biology results for three consecutive years for the two schools were relatively the same. The implementation was done within eight weeks to complete the topic selected. In the present study, seven students dropped down but their tests were removed from the analysis. Also shortening the time for implementation in which eight weeks were used from pre-test to post-test to avoid dropping out from the study. The test items between pre-test and post-test were the same. The observer was the same throughout and the scorers were the same using the same marking guide and rubric. The control group and experimental group were not in contact as they were 50 km apart. Also, both schools were not informed about the pre-test and post-test.

Data Analysis

Data from the achievement test and questionnaire were analyzed with the help of Statistical Package for Social Sciences (SPSS) Version 24. The paired sample t-test was computed to find out the differences in students' mean scores in the achievement test between pre-test and post-test at a significance of 95% ($p<.05$) (2-tailed). Also, an independent sample test was computed to find the achievement of students in the six cognitive skills namely; *remembering, understanding, applying, analyzing, evaluating, and creating* to test if there was a statistically significant difference in cognitive skills between experimental and control schools. Data from the questionnaire were fed into SPSS where a paired sample t-test was computed to test if the changes that occurred from pre-test and post-test were statistically significant at a level of 95% ($p<.05$) (2-tailed). To measure the effect size in the achievement test and questionnaire, the eta squared value (e^2) was computed. The interpretation of effect size was as follows: .01 = small effect size; .06 = medium effect size; and .14 = large effect size.

Findings

Research question number one intended to assess if there was a statistically significant difference in mean scores between using PBL and using traditional methods on the topic of Safety in Our Environment. The overall results show that there was an increase in mean scores from the pre-test in the experimental school after using PBL. The increase of the mean score is statistically significant at $p = .00$ with a large effect size ($e^2 = .11$). In the control school, the results show that there was a decrease in mean scores from pre-test to post-test. The decrease in scores however is not statistically significant at $p = .127$ after using traditional methods. The study dealt with the basic science process skills that are very important to be acquired at the lower levels of education. These are observation, communication, measurement, classification, prediction, and inference skills. The results obtained after implementing the topic of Safety in Our Environment using PBL in experimental school and traditional methods in control school are presented in Table 3.

Table 3

Paired Sample t-test Results on Development of Science Process Skills

	Experimental school (n = 38)						Control school (n = 42)					
	Pre-test		Post-test				Pre-test		Post-test			
Science process skills	M	SD	M	SD	t	Sig (2-tailed	M	SD	M	SD	t	Sig (2-tailed
Observation	2.61	0.789	3.70	0.690	6.66	0.00	3.39	1.064	3.42	0.870	0.27	0.79
Communication	3.55	1.003	4.44	0.878	4.48	0.00	4.24	1.000	4.11	1.057	0.77	0.45
Measurement	2.11	0.725	2.77	0.709	4.05	0.00	2.81	0.881	2.79	0.793	0.16	0.87
Classification	2.35	0.736	3.07	0.588	4.44	0.00	3.02	0.721	2.68	0.868	2.44	0.02
Prediction	2.80	0.917	3.77	0.764	5.86	0.00	3.84	0.816	3.35	0.917	3.30	0.00
Inference	2.86	1.147	3.80	0.858	4.24	0.00	3.37	0.964	3.45	0.997	0.65	0.52

Note: M = Mean, SD = Standard deviation, t = t-statistic value

As indicated in Table 3, the paired sample t-test conducted shows that there was an increase in mean scores from pre-test to post-test after using PBL in developing observation skills in an experimental school. The increase in mean score is statistically significant at p = .00 with a large effect size (e^2 = .11). In the control school, the results show that the mean score increased from pre-test to post-test using traditional methods. The increase in mean score is not statistically significant at p = .79. Concerning communication skills, the results show that there was an increase in mean scores from pre-test to post-test after implementing the topic using PBL. The increase in mean score is statistically significant at p = .00 with a medium effect size (e^2 = .07). Using traditional methods in control school in developing communication skills shows a decrease in mean score from pre-test to post-test. However, the decrease in mean scores is not statistically significant at p = .45.

Regarding measurement skills, the results show that there was an increase in mean scores from pre-test to post-test after using PBL. The increase of the mean score is statistically significant at p = .00 with a medium effect size (e^2 = .07). In the control school, the results show that there was a decrease in mean score from pre-test to post-test. The decrease in mean score however is not statistically significant at p = .87. The mean score in classification skills also was increased from pre-test to post-test after using PBL. The increase in mean score is statistically significant at p = .00 with a medium effect size (e^2 = .07). Teaching and learning on the topic of safety in our environment using traditional methods show a decrease in mean scores from pre-test to post-test towards developing classification skills. The decrease in mean scores is statistically significant at p = .02.

Furthermore, the paired sample t-test results indicate that there was an increase in mean scores in developing prediction skills from pre-test to post-test after using PBL. The increase in mean score is statistically significant at p = .00 with a large effect size (e^2 = .1). Using traditional methods in developing prediction skills caused a decrease in mean scores from pre-test to post-test. The decrease in mean scores is statistically significant at p = .00. In developing inference skills, the paired sample t-test conducted indicates that there was an increase in mean scores from pre-test to post-test after implementing PBL. The increase in mean score is statistically significant at p = .00 with a medium effect size (e^2 = .07). Traditional methods show an increase in mean scores in developing inference skills from pre-test to post-test. However, the increase in mean score is not statistically significant at p = .52.

Research question number two intended to assess if there was a statistically significant difference in mean scores between using PBL and using traditional methods in achievement test on the topic of safety in our environment. The results from the paired sample t-test conducted indicate that there was an increase in mean score from pre-test (M = 20.41, SD = 13.49) to post-test (M = 34.92, SD = 25.24). The increase in the mean score is statistically significant at p=.00 with a large effect size (e^2

= .1). In the control school, the paired sample t-test conducted shows that there was an increase in the mean score from the pre-test (M = 26.33, SD = 11.58) to post-test (M = 29.17, SD = 12.84). The increase in the mean score is not statistically significant at p = .051.

An independent sample t-test was conducted in order to obtain the effect of PBL on the achievement of students in cognitive levels as suggested by the CBC on the topic of Safety in Our Environment. The results are presented in Table 4.

Table 4

An Independent Samples t-test Results for the Achievement test for the Topic of Safety in Our Environment

Test items and cognitive levels	Experimental School n =38		Control School n =42				⁑Effect size
						*p**	(eta squared)
	M	SD	M	SD	*t*		
Remembering (5 items)	6.47	7.120	3.98	1.631	2.119	0.040	0.05
Understanding (3 items)	5.16	5.149	4.07	3.904	1.095	0.278	0.01
Applying (3 items)	8.71	4.099	8.15	4.958	0.574	0.567	0.00
Analysing 2 items)	4.50	2.826	4.07	2.826	0.704	0.483	0.01
Evaluating (2 items	3.08	4.315	1.07	1.931	2.682	0.010	0.07
Creating (2 items)	6.05	6.726	6.28	5.108	-0.182	0.856	0.00

Note:*is significant at p < 0.05 (2-tailed)⁑effect size: 0.01 = small effect size; 0.06 = medium effect size; 0.14 = large effect size

The results indicated in Table 4 show that the use of PBL had some differences in achievement in cognitive skills. In remembering skills, PBL shows a statistically significant increase in mean scores at p = .040 with an almost medium effect size (e^2 = .05) as compared to the traditional methods. Evaluating skills is developed at statistically significant at p = .010 with a medium effect size (e^2 = .07) as a result of using PBL in the achievement test. However, there are no statistically significant differences in achieving applying skills and creating skills implying that PBL and traditional teaching methods yielded almost the same results.

Research question number three aimed at establishing if there were gender differences in means scores before and after the implementation of PBL in the experimental school and traditional methods in the control school on the topic of Safety in Our Environment. The results are presented in Table 5.

Table 5

Gender Differences in Mean Scores between Pre-test and Post-test in Achievement Test

		Experimental school (n=38)			Control school (n=42)		
	Gender	N	M	SD	N	M	SD
Pre-test	M	22	19.77	13.384	25	29.68	13.496
	F	16	20.94	13.665	29	23.45	8.899
Post-test	M	22	33.82	23.528	25	31.12	14.336
	F	16	36.31	27.383	29	27.48	11.388

An independent samples t-test was conducted to compare the pre-test scores for males and females in the experimental control school before the implementation of PBL. As indicated in Table 5, the results shows that there was no significant difference in scores for males (M = 19.77, SD = 13.384),

and females (M = 20.94, SD = 13.665) t (36) =-0.263, p = .794. The magnitude of the differences in the means was very small (e^2 = .002). After the implementation using PBL for developing SPS, an independent samples t-test was conducted to compare the post-test scores for males and females in the experimental school. The results shows that there was no significant difference in scores for males (M = 33.82, SD = 23.528), and females (M = 36.31, SD = 27.383). The magnitude of the differences in the means was very small (e^2 = .002).

Also, an independent samples t-test was conducted to compare the pre-test scores for males and females in the control school before teaching the topic of Safety in Our Environment using traditional methods. The results shows that there was no statistically significant increase in scores for males (M = 29.68, SD = 13.496), and females (M = 23.45, SD = 8.899). The magnitude of the differences in the means was medium (e^2 =.07). After teaching the topic for eight weeks, an independent samples t-test was conducted to compare the post-test scores for males and females in the control school. The results shows that there was no significant difference in scores for males (M = 31.12, SD = 14.336), and females (M = 27.48, SD = 11.388) t (40) = 1.039, p = .304. The magnitude of the differences in the means was small (e^2 = .02).

Discussion

This study aimed to examine the effect of the PBL approach on developing students' SPS and learning achievement in the topic of Safety in Our Environment in secondary schools in Tanzania. The SPS investigated in this study are observation, communication, classification, measurement, inference, and prediction. PBL has shown that it has the power of developing SPS compared to traditional teaching methods. The results for the ability of PBL to develop SPS indicate a significant change after the implementation. This increase in performance in developing SPS could be highly attributed to the systematic use of PBL in the selected topic as opposed to traditional methods. During implementation using PBL, students were directed through eight steps as per Bokonjic et al. (2009) with various activities that each student took part in towards solving the identified problem. This is contrary to the traditional methods in which students were not given chance to explore the word inherent in the topic. It is clear that the use of traditional methods in which the teacher is the information giver while students are the information receivers has little contribution to the learning of science subjects including biology. This again is contrary to the CBC that took place in 2005 with emphasis on developing competencies and SPS in secondary schools in Tanzania.

Moreover, the use of PBL has been shown to have an impact on the development of all six SPS contrary to what the traditional methods do. Observation skills which are very important for science learning seem to be developed as a result of PBL where the change is significantly large compared to traditional teaching methods. Observation skills have been documented in the curriculum in use where students have been directed to use the five sense organs to observe the phenomena under study. For example on the topic of Safety in Our Environment students have been directed to observe various components required in the provision of First Aid to various victims. Also, they have been directed to observe various ways of waste disposal in the surroundings. PBL has shown its ability in developing communication skills compared to traditional teaching methods that show a decrease from pre-test to post-test. Wijnen et al. (2017) and Yoo & Park (2015) found similar findings regarding the impact of PBL on developing communication skills. Similar trends are observed for measurement, classification, prediction, and inference skills. These results concur with the study conducted by Athuman (2017), Maranan (2017), and Yadav and Mishra (2013) on the effect of inquiry-based learning approaches on developing SPS.

Concerning students' achievement in the test, a paired t-test on the use of PBL shows a statistically significant difference in performance as compared to traditional methods. While the mean increase is 14.51 in the experimental school, the mean increase in the control school is 2.83. These results are similar to the study by Odell et al. (2019) which was conducted for five years whereby two years (2013-2014) were pre-intervention while three years (2015-2017) were accompanied by intervention using PBL in mathematics, science, reading and writing examinations. In their study, the

results indicated improvement in students' scores from pre-intervention to post-intervention in all four subjects.

Poor performance in science subjects at the secondary school level including Biology has been increasing following the adoption of the CBC in Tanzania in 2005. Factors for such poor performance have been described in the literature, and include lack of teaching and learning materials (Kasuga, 2016; Maro, 2013), insufficient in-service training (Kasuga, 2016; Luvanga, 2017; Mbwile, 2020), inappropriate teaching methods, (Kasuga, 2016; Maro, 2013) and a large number of students per class (Kasuga, 2016; Luvanga, 2017; Maro, 2013). The government has tried to minimize those factors but the trend of student academic performance in those subjects has remained unchanged over the years. In addressing those factors, there seems to be less attention given to the teaching methods adopted by teachers in delivering their lessons. As a result, the persistent use of traditional methods has contributed to poor performance to a high degree as compared to other factors (Kasuga, 2016; Lazonder & Harmsen, 2016; Luvanga, 2017; Maro, 2013; Wandela, 2014; Tawfik et al., 2020; Demirçalı, & Selvi, 2022). The use of learner-centered methods such as activity-based learning (Maro, 2013), inquiry learning (Luvanga, 2017), and outdoor activity (Mbwile, 2020) have shown to raise students' interest in learning science subjects, hence improving their performance in the subjects. The use of the PBL as indicated by the results of this study has shown significant impacts on developing students' science process skills as well as increased students' academic achievement. The contribution of PBL to students' achievement is practically significant and it needs attention from both policymakers and implementers of the curriculum. It calls for an immediate shift from traditional methods to learner-centered methods in order to meet today's era of competence-based, outcome-based, and technological-driven, 21st-century skills requirements and global competition in the labor market.

This study also aimed to examine if there were differences in the mean scores between males and females in the experimental school and control school before and after the implementation. The results indicate that there is no statistically significant difference in performance between males and females in experimental school for both pre-test and post-test mean scores with a very small effect size at both pre-test and post-test (e^2 = .002). In the control school, the results show that there was no statistically significant difference in mean scores between males and females at pre-test with medium effect size (e^2 = .07) and small effect size at post-test (e^2 = .02). Performance in science subjects including biology has been an agenda worldwide where females have reported to underperform compared to males. Factors for such differences have been reported including the teaching methods employed by teachers in the classroom (Maro, 2013, Mwile, 2020). The use of traditional methods has limited females to exercise their potential in science learning including biology in favor of males. The use of PBL has shown a big step towards balancing the gap that exists in the literature. The current study has demonstrated that the performance of males and females after using PBL is not different as compared to the performance of males and females who went through traditional methods. The use of PBL fosters group discussions among students and makes individual learners experience a sense of ownership of the learning process compared to traditional methods (Bokonjic et al., 2009). The literature indicates that males are generally more aggressive and competitive than females and tend to be less collaborative hence the didactic methods such as traditional methods favor males more than females (Maranan, 2017).

Issues of gender equity and equality in education are now being emphasised even in curriculum reforms in different countries. The curriculum adopted in Tanzania in 2005 for example, indicates provision of equality and equity in education especially the use of teaching methods that provide opportunity for both males and females to participate in the learning process and hence raise the performance for all students. We have experienced recently that the number of females enrolled in the lower secondary schools is higher than that of males (BEST, 2019), but become extremely lower as you go further in higher education especially in science subjects (BEST, 2019). One of the factors for such spontaneous decrease in numbers of females taking science subjects is the use of didactic methods in teaching such as traditional methods (Mbwile, 2020; Kasuga, 2016). The findings of this

study have indicated that using learner-centred methods such as PBL reduces the gap in performance between females and males.

Conclusion and Recommendation

This study intended to assess on how PBL can develop SPS and learning achievement in the topic of Safety in Our Environment. The findings have demonstrated that PBL approach can enable students to develop SPS by far as compared to the traditional teaching methods. Also the use of PBL has shown to increase students' scores in the achievement test compared to the traditional teaching methods. Traditional teaching methods have the ability to retain achievement at low level of cognitive ability as compared to PBL. Furthermore, PBL has shown to have no difference in achievement between males and females as compared to the traditional teaching methods. The study recommends a critical change from persistent use of traditional methods to using learner-centered methods as suggested by the CBC. There is a need to shift from using traditional teaching methods to learner-centered methods such as PBL in order to go parallel with the changing world. As many countries are geared toward industrialization, developing SPS of students using learner-centered methods such as PBL will make them fit into the world of business.

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Appendices

Appendix A: Table of Specification Used in Construction of Test İtems

Table: A

Tables of Specifications in the topic of Safety in Our Environment

TYPES	OBJECTIVES/COMPETENCES						Total
	Remembering	Understanding	Applying	Analyzing	Evaluating	Creating	
MCQ	3	2	2	1	1	1	10
SA	2	1	1	1	1		6
ES						1	1
Sub-Total	5	3	3	2	2	2	17

Note: MCQ=Multiple Choice Questions, SA=Short Answers, ES=Essay,

Appendix B: A Sample of Lesson Plan İmplemented in Classroom

Subject: Biology Teacher's Name: Teacher 1

Date	Class/stream	Period	Time	Number of students					
17/8/2020	Form 1E	1st & 2nd	7.40-9.00	Registered			Present		
				M	F	T	M	F	T
				18	20	38	-	-	-

Main Topic: Safety in Our Environment
Sub-Topic: Waste disposal
Problem: Effects of wastes disposal in the environment: Landfill problems: Air pollution and health hazards. Learners were asked to read the resources on landfills and their effects on the environment. Their educational programme had to suggest the advantages and disadvantages of landfills, and suggest strongest reasons why a community should campaign against the beginning of any new landfill on their community land. They then had to plan a campaign that would galvanise their community to protest against a new landfill in their community by using either posters, letters to their village leaders, a community rally, or a radio programme.
Competences: students to have the ability of solving problem related with waste disposal
Teaching and Learning Materials: Various resources related to landfills and effects of poor waste disposal to the environment

Lesson Development

Stages	T(M) 80	Activities	Intended SPS to be developed
Clarifying terms	5	The students prepared four columns in their exercise. The unknown terminologies were clarified for this terms related to demonstrating proper ways of disposing waste, explaining the effects of poor waste disposal and suggesting proper ways of disposing waste in the surrounding community. What is known about these terms was presented in the respective column on the exercise books.	Observation skills and Communication skills
Defining the problem	5	In this stage, discussions on the problem and the methods that were used to find the solution. The identified problems were written down in the respective column in the exercise book.	Observation skills, prediction skills and communication skills.
Brainstorming	5	Students in small groups discussed on the problem using their prior knowledge the ideas on demonstrating proper ways of disposing waste, explaining the effects of poor waste disposal and suggesting proper ways of disposing waste in the surrounding community. During this step all students were encouraged to speak their mind and all ideas were valued and noted.	Prediction skills and communication skills

Hypothesis	5	By using step ii and iii, students provided explanations on demonstrating proper ways of disposing waste, explaining the effects of poor waste disposal and suggesting proper ways of disposing waste in the surrounding community and came up with final hypotheses/explanations, which were then written down in its respective column.	Prediction skills and communication skills
Learning objectives	5	The student formulated the objectives which were written in its respective column. In this case the objectives were to (i) demonstrate proper ways of disposing waste (ii) explaining the effects of poor waste disposal and (iii) suggesting proper ways of disposing waste in the surrounding community	
Searching for information	35	Individual students were required to find resources required to answer the stated objectives and come with as many possible answers. This provided the students with a more profound knowledge regarding demonstrating proper ways of disposing waste, explaining the effects of poor waste disposal and suggesting proper ways of disposing waste in the surrounding community.	Observation skills, communication skills, measurement skills, classification skills, prediction skills and inference skills
Synthesis	20	During this step the members of the group shared the results of the individual findings. With this new information they analysed the stated problem and they came up to an understanding of, and solution to the identified problem.	Communication and inference skills