

Effect of Project-Based Learning: Learners' Conceptualization and Achievement in Science Education

Jean Nepomuscene Twahirwa¹, Celestin Ntivuguruzwa¹, Etienne Twizeyimana² & Theophile Shyiramunda³

Abstract

Over the past decades, academic interests in teaching and learning approaches emerged alongside the modernization discourse of the education sector. Since then, a paradigm shift from consideration of education as art to science is observed. Although project-based learning approach seems important in enhancing the overall academic achievement of learners, a willingness of teachers to implement it, remains critical and its implication in science education became an integral matter of serious concern. The current study used a quasi-experimental design to determine the effect of the project-based learning approach (PBLA) on the academic achievement of learners in science education in Rwanda. This article provides an insight into how educators consider the use of some specific teaching approaches relevant in the 21st century and articulates the advantages of PBLA. The null hypothesis was rejected based on the results obtained as the p-value was less than 0.05 ($p < 0.05$). Though some participants demonstrated a strong confusion about the role of the project-based learning approach, the current study exposed unparalleled benefits linked to the proper design and implementation of PBL in the teaching and learning process. There is a positive effect in overall academic performance of learners in science subject when PBL is properly designed and integrated into teaching and learning processes.

Keywords: Quasi-experimental design; project-based learning approach; students' academic performance in science

Introduction

Education sector in the 21st century is progressively integrating innovative and creative teaching and learning modalities, particularly in science subjects. Historical throwbacks indicate that expository teaching approaches gained reputation for delivering instruction. However, the learning comfortability on the side of learners has been critically evaluated. Through these approaches, only passive learning, which in turn conveys surface knowledge, takes place. Previous studies indicated that during

expository teaching approaches, the teacher is the sole decision maker through direct provision of course content, demonstration of scientific formula and concepts thereby making learners the followers rather than participants in the teaching and learning process (Ramdhani, Usodo, & Subanti, 2017).

Trending teaching and learning approaches in the 21st century includes learner-centered methodologies such as induction method, project-based learning, inquiry and several other methods that have been seen to be promising in teaching and learning endeavors.

¹Jean Nepomuscene Twahirwa & Celestin Ntivuguruzwa are at the African Centre of Excellence for Innovative Teaching and Learning Mathematics and science (ACEITLMS), University of Rwanda, College of Education (UR-CE), P.O. Box 55, Rwamagana, Rwanda. Emails: jeannepomuscenetwahirwa@gmail.com

²Etienne Twizeyimana, Kiyumba TVET School, Muhanga & Mount Kenya University, Kigali. Rwanda. E-mail: etienne.twizeyimana@yahoo.com

³Theophile Shyiramunda is at the Leipzig University, 04109 Leipzig, Germany. Email: t.shyiramunda@studentserv.uni-leipzig.de

Presentation of instructions is not an easy task as one can imagine. It requires the instructor to devise the method that facilitates the learner to look for patterns in a specific manner and then based on careful observation, the learner may draw conclusion that may be generalized to similar patterns. This approach is referred to as induction or bottom-up approaches as opposed to deduction methods, which uses top-down approaches from general inferences to specific ones.

In order for learners to develop contemporary skills, teachers have been working tirelessly towards encouraging teaching and learning approaches. Apart from the earlier mentioned methods, the project-based learning (PBL) is another popular and trending teaching and learning approach that captures learners' attention and impart strong and desirable skills after schooling period. Project-Based Learning (PBL) is defined as a learner-centered, teacher-facilitated approach to learning. During the process, learners acquire skills and knowledge through inquiring on their inner curiosity therefore learners develop the sense of critical thinking based on teachers' guidance. In this article, we explore the Effect of Project-Based Learning Approach on learners' Conceptualization and Achievement in science education.

Expository Learning Approach versus Project-based Learning Approach

In the following subsections we explore expository learning approach versus project-based learning approach (PBLA) and then advantages of project-based learning approach (PBL) are sightseen.

Expository Learning Approach

Expository teaching and learning approaches have been for long explored as strategies leading to passive learning in which students are not actively involved in the teaching and

learning process (Dignath & Veenman, 2021). Due to the nature of expository methods in instruction delivery, the classroom atmosphere seems to be boring and students passively follow instructions, hence poor understanding and conceptualization of instructions (Roberts, 2019). The expository learning is hereinafter termed the banking model of learning. The banking model of learning sees teacher as a source or a house of knowledge who should fill the knowledge to the minds of learners (Regmi, 2012; Wang, 2017).

Briefly, in the banking model, the teaching and learning nature focuses on contents not on the learners as result of direct provision of contents to the learners to memorize mechanically and reproduce them during assessments or examinations. A banking approach marginalizes the critical powers of the learners and increases upshots to the instructor participation. However, a study conducted by Baker, Goodboy, Bowman, & Wright (2018), asserted the instruction delivery to be dialogical, meaning that teacher-learners and learner-learners should interact and share the knowledge and skills. Sharma & Kumar (2018) argue that the expository teaching method is a chalk and talk teaching where teacher stand on the board with chalk and expose the contents to the learners.

The vibrant technology-led teaching and learning coupled with innovative and creative endeavors of involved educational professionals received attention in the past couple of decades. Globally, transitions from deductive approaches to inductive approach, expository teaching to inquiry-based teaching and constructivism to the social constructivism, humanistic to social humanistic approach and self-determination theory have been remarkably undertaken. In

line with the research advanced by Ayaz & Sekerci (2015), the environment directed by social constructivists learning stimulates learners' motivation and encourages team working spirits. Nowadays teaching and learning through discovery modalities is at the forefront in education particularly in science education.

Project-Based Learning Approach (PBLA)

Project-Based Learning (PBL) is a groundbreaking approach in education that involves teaching through assembly of strategies and has been promising in the current era dominated by rapidly developing technologies worldwide. This learning approach necessitates students to work cooperatively, collaborate towards fruitful project creation, and come up with research results from their own work. The project-based learning involves self-directed learning, investigation and exploration of the concepts, which all facilitate the learning in permanent coding of the concepts that could enhance easy retention and conceptualization process. The project-based learning takes the move of predict-observe-explain-conclude and this foster the students' prediction abilities and critical thinking that support the process of understanding complex concepts presented in science subjects according previous study (Alfiyanti & Jatmiko 2020). Additionally, the project-based learning involves problem-solving tasks that enhances the student's creativity and innovation which in turn promotes logical capacities in science education (Twahirwa & Twizeyimana (2020), and involves practical tasks such as manipulating activities that could raise the hands on and minds efficacy.

The successful design and implementation of project-based learning approach in science subject teachings involves various steps. Some of them are for example, (1) identification of the issue, (2) formulation of the issues and associated hypothesis, (3)

searching and gathering related data, (4) proving the data through experiments to test the reality, (5) resenting and defending the tested reality, (6) clarifying the wrong results, (7) summarizing the process, and drawing conclusion (Usmeldi ,2018). However, by inferences, the project-based learning has been at a given extent undermined by teachers due to several constraints. Generalized factors include insufficient time allocated to science subjects, dominance of teacher-centered teaching, inadequate teacher training and workshops, scarcity of experimental tasks. It is also worth to note that in some schools, the lack of creativity and innovation to improvise materials supplementing conventional materials constitutes a big challenge towards the implementation of PBL approaches.

The consequence of these ways of working could result into poor overall academic performance and incompetent school leavers, as well as high rate of repetition in secondary schools. The quality of science subject package received by students could be successfully attained when there is a close interaction between teacher-learner and learner-learner accompanied by guided creativity and innovation. The overall hypothesis of this study is that project-based learning could enhance conceptualization and achievement in science education.

Advantages of Project-Based Learning Approach (PBL)

Systematic exploration of potential paybacks of PBL in contrast to traditional approaches of learning, the review of existing literatures and own perspectives on PBL was thoroughly compiled

Traditional teaching and learning approaches have been linked to poor learning outcomes, and there is a need for shifting from traditional approaches in education to approaches that actively engage learners into the process of learning. A study conducted by Pratama, Ranti, Usmeldi, & Syafriani (2019), asserted

that learners who do not actively participate in the knowledge and skills construction do not learn optimally whereas in project-based learning, learners are the primary source of physics. In connection with the study by Haryanto & Arty (2019), the higher-self efficacy is only attained through discovery which can be defined as an active learning

Table 1 Potential advantages of Project-Based Learning Approach

Reviewed advantages of Project-Based Learning	Sources
a. Promotes creativity and critical thinking ability	Sasson, Yehuda, and Malkinson (2018)
b. Instills in learners the ability to communicate effectively	Owens and Hite (2020)
c. Enhances relational teamwork, and promotes innovative thinking	Barak and Yuan (2021); Vogler et al. (2018)
d. imparts specific knowledge and skills while inspiring student to question actively and think critically	Shah, Patel, and Chhatrivala (2021)
e. Promotes interactive learning	Wurdinger and Qureshi (2015)
f. Allows learners to develop the sense of responsibility and accountability	Jamal and Tilchin (2016)
g. Develops in learners the ability of problem identification and problem-solving ability	Kartini, Widodo, Winarno, and Astuti (2021)
h. Data collection and analysis skills and research skills	Latada and Kassim (2017)
i. Time management, work plan and execution, and so forth	Santyasa, Rapi, and Sara (2020)

information which develop learner's accountability and cognitive capacities (Lau, Kitsantas, Miller, & Rodgers 2018).

Rap, Feldman-Maggor, Aviran, Shvarts-Serebro, et al. (2020) articulate that the technology is an essential element of project-based learning which is associated with the video, simulations, presentation that helps in easy understanding of complex concepts. The incorporation of videos and simulations in learning stimulates students' scientific inquiry and self-efficacy that enhances the retention and widen mind's capacities. Self-efficacy can be defined as either higher or lower self-efficacy of an individual to accomplish the activities. According to Hasanah, Sholihin, & Nugraha (2021), the learners with higher self-efficacy become higher achiever's while learners with lower self-efficacy are lower achievers as result of being disinterested in

which looks at the existence of realities. Discovery is a transition of learning from abstract facts to the observable facts. Self-discovery learning is in line with the constructivist's views of research-based learning that takes learners as focal point in learning where truly meaningful knowledge is constructed from prerequisite bits of storage information and thus learners may need instructor facilitation and, in that case, becomes a mentor.

The research-based learning uses multifaceted approaches such as cooperative learning, learning by doing, problem-solving, experimentation, investigation which strengthen students' contextual abilities and easy mastering of physics concepts that yields fruitful academic achievement. Experimentation and investigation instill in learners' profound competences that supports

in searching, collecting, scrutinizing, information and prediction. A study by Utami, Probosari, Saputro, & Masykuri (2019), physics involves testing the truth through experiments that gives the students chance to obtain theoretical concepts and its real-life applications. All aforementioned advantages contribute to student's conceptualization and academic achievement.

Does the implementation of Project-Based Learning really matter?

Although Morrison et al. , 2020, advocate that autonomous learning exclusively teacher-learner and learner-learner interaction could not yield the meaningful learning, the keystone to have quality project-based learning is to have strong teacher-learner interaction. In line with Sunarno (2019) findings , the excellent academic performance, learners' regular attendance could be raised only through construction of strong interaction between teachers and learners.

The study carried out by Choi, Lee, & Kim (2019), indicated that the students who have health interaction with their teachers were likely to develop positive attitudes, research spirits and perform better towards the subject whereas the students with poor interaction with teachers tend to develop disruptive behaviors and negative interests. In another study, it has been demonstrated that the quality interaction between teachers-learners determine students' motivation and engagements; whereas the conflicting relationship with the instructor or teacher leads to the feeling of insecurity in learners (Zadok ,2019). This has been also supported by Guo, Saab, Post & Admiraal (2020), the friendship environment and positive interaction are the powerful weapons to shape quality research-based learning which ultimately influence both students' conceptualization and academic achievements.

According to Zhang & Zhang (2020), the positive strong interaction between teachers and learners maintains motivation and active participation which is in discrepancies with conflicting interaction that deteriorate learner's engagement as results of worse outcomes. According to the study conducted by Tsai, Liao, Chang, & Chen (2020), strong interaction during instruction delivery supports teachers to identify learners needs, learning potentials and difficulties as a way forward of finding the right techniques to facilitate in research learning. Based on the aforementioned details, the peer's interaction and learner-teachers interaction have a fruitful influence on students mastering of contents and academic achievement. It is based on the advantages tied to project-based learning, which is a learner-centered learning in its nature.

Research objectives and hypotheses

1. To show the effect of using project-based learning approach on science students' performance
2. To investigate science teachers' views on effectiveness of project-based learning and their reflection on its impact on students' conceptualization and retention of the content.
3. To identify factors contributing to poor implementation of project-based learning in secondary schools.

To investigate the effect of project-based learning approach on students' academic achievements, a null hypothesis was developed to respond to the first research objective. For subsequent study objectives, we preferred to use research questions.

H₀: There exist no significant difference in conceptualization and achievement in science of learners' who were taught using PBL approach and those taught using normal traditional learning approach.

Methods

This study investigates the effect of the project-based learning approach on conceptualization and achievements in science education. In this section, details on the research design and research instruments, study population and sampling techniques, data collection procedures and analysis are provided.

Research design and tool

The research inaugurated with discussion as a way of detecting and investigating the reason behind the poor achievement on the course unit called "heat and temperature" taught in physics. Thereafter, the present research adopted the quasi-experiment research design, specifically pretest posttest non-randomized control group among learners of senior one G.S Gihinga in Kayonza district-Rwanda. Moreover, views on the effect of project-based learning approach were collected through a designed online Secondary School Science Teachers' questionnaire (3STQ).

Study population and sampling techniques

The study population comprised learners from Groupe Scholaire Gihinga in Rwanda selected through non-random sampling techniques. There was no further determination of sample size because all learners were present in the class during teaching and learning process. The total number of study participants was 106 learners and 40 secondary school science teachers selected randomly in different secondary schools.

Data collection procedures

Prior to conducting the current study, the pilot study was designed using Physics Achievement Test and was administered to deliberately sixty selected learners of the secondary school specifically Ecole Secondaire Nyarubuye located in Kirehe

district of Rwanda. The pilot study was composed of 23 questions, and based on the results obtained from the pilot study and interview conducted with learners; it was perceptible most of learners failed 17th, 10th and 7th questions. Three questions were removed from the set of twenty-three questions; the remaining questions were used for further exploration on the Effect of Research-Based Learning on Conceptualization and Achievement in Physics among Learners of Ordinary Level in Kayonza District. The study participants were from three classes at G.S Gihinga namely S1A, S1B and S1C with the total study population of 106 learners. Informed consent form was issued to learners for voluntary participation in the study. All 106 learners returned the signed agreement of voluntary participation.

Data collection procedures were divided into four phases. The first phase was to administer the Physics Achievement Test taken as the pre-test in this study to the control and experimental groups to identify the learners' prerequisite knowledge and skills and misconceptions about heat and temperature, a lesson extracted from unit nine in the Competency-Based Curriculum (CBC) currently used in Rwanda education system. The second phase was to expose learners from the experimental group to a different learning method, that is, the project-based learning approach (see Appendix III), while the learners from the control group are still being treated by lecturing method.

Learners from the experimental group were provided learning facilities including ICT tools, handbooks, and simple laboratory equipment such as thermometer, beakers, and water as well. The third phase was to prepare the Physics Achievement Assessment (PAA) referred to as the posttest to the learners from

both control and experimental groups to measure their in-class performance. The fourth phase was to record the results from both groups, and kept for next steps.

Data analysis and presentation

The final phase was to administer the posttest to the control and experimental group to see the contrasted method after being given different intervention. Thereafter, the collected data were kept for next step and analyzed by SPSS version 21. As described on the aforementioned above sections, the inadequate resources, poor interaction between teacher-learners and learner-learners, lack of improvised materials to supplement the conventional materials, lack qualified teacher and creativity and innovation could hamper the smooth learning and teaching activities, which in turns affect academic achievements in physics.

Results and discussion

In the following section results are presented and discussed. The demographic description

of the study participants are presented in Table 2.

In the present study, the participant’s demographic description was an important parameter that helped researchers to validate the presented findings. It was crucial to understanding the size of participants, for teachers, we thought that age, gender, taught level qualification, experience, and specialty might influence the performance of teachers while they concentrate on their teaching profession. As neatly displayed in Table 2, learners and secondary school science teachers participated in the study. The one hundred and six learners were involved in the research process including 45 boys and 61 girls corresponding to 42.5% and 57.5% respectively to avoid gender-based prejudices. Although the participation of boys was slightly higher than that of girls, this could not limit the researcher to consider voices of girls’ participation. As teachers of different ages are believed also to respond differently to

Table 2 Demographic characteristics of the study participants

Characteristic	Number (%)¹	Characteristic	Number (%)
Learners			
<i>Gender</i>			
Boys	45 (42.5)		
Girls	61 (57.5)		
Teachers			
<i>Teachers’ age</i>		<i>Teachers’ Gender</i>	
20-30 years	17 (42.5)	Males	25 (62.5)
30-40 years	23 (57.5)	Females	15 (37.5)
<i>Teaching level</i>		<i>Teachers’ qualification</i>	
Ordinary level	24 (60.0)	Diploma	18 (20.0)
Advanced level	16 (40.0)	Bachelor’s degree	32 (80.0)
<i>Teaching experience</i>		<i>Teachers’ specialty</i>	
1-5 years	18 (45.0)	Physics	16 (47.5)
6-10 years;	15 (37.5);	Chemistry	12 (30.0)
above 10 years	7 (17.5)	Biology	9 (22.5)

Source: primary data, 2021;

¹Percent in parenthesis

working environments and conditions, showing the age category of participants could help readers to match the results with the working staff in their respective workplaces. Therefore, 17 teachers were in the range of 20-30 years and 23 in the range of 30-40 years corresponding to 42.5% and 57.5% respectively. To ensure equity in gender-based participation on the side of teachers, the research involved 25 males and 15 females corresponding to 62.5% and 37.5 % respectively.

Another demographic parameter was to associate teachers with the level at which they teach. In this regard, 24 teachers were teaching at the ordinary level and 16 were teaching in the advanced level corresponding to 60.0% and 40.0% respectively, hence teachers who participated in this research represent categories of teachers in the lower and upper secondary cycle. Moreover, teachers' degree category and their teaching experiences were taken into account. Hereafter, 18 teachers with a diploma and 32 with bachelor's degrees corresponding to 20.0% and 80.0% respectively took part in the study with their teaching experiences as follows: 18 teachers were in the range of 1-5 years, 15 teachers in the range of 6-10 years and 7 teachers whose experience was above 10 years corresponding to 45.0%, 37.0%, and 15.5% respectively. Thereafter, the authors indicated the specialty of participating secondary science teachers where 16 teachers specialized in Physics, 12 specialized in Chemistry, and 9 in Biology corresponding to 47.5%, 30.0%, and 22.5% respectively. All this demographic information could facilitate readers to integrate the findings of this study contextually.

In this work, perceptions of teachers on PBL were gathered through preset assumptions, and findings are indicated in Table 3. The participated science teachers expressed views about the effectiveness of project-based learning (PBL) and its effect on learners' conceptualization and achievement. As a modern learning modality, PBL maximizes students' learning and arouses their interest. We wanted to understand respondents' consideration of PBL, and 40% and 60% corresponding to 16 and 24 respectively asserted that the investigated approach comprises collaborative learning and group focus discussion both of which facilitate critical thinking, creativity, and easy retention of science contents. They further confirmed that PBL embraces practical work, cooperative learning elements both of which equip learners with practical and team working skills as indicated by 82.5% corresponding to 33 respondents. The remaining 17.5% corresponding to 7 participants declined the assumption; however, the findings could be generalized depending on a high percentage of positive responses. About 90% corresponding to 36 out of 40 participated teachers disclosed that learners possess preliminary knowledge and skills on which the teacher should base on. Therefore, they should involve in the improvisation process.

Although the PBL is regarded as the promising method, 87.5% corresponding to 35 said that poor implementation of the approach reduces learners' ability to store information in the long-term memory while 70% of all respondents revealed that poor implementation of PBL negatively affects learners' motivation and attention, which in turn leads to poor understanding and retention

of science contents. Another parameter that could hinder the implementation of PBL as indicated by 87.5% of respondents is the lack of continuous professional development (CPD) arrangement such as workshops and pieces of training to the serving teachers. Returns of this factor negatively affect the proper use of PBL. To sum up, disagreement and neutrality occurrence in the findings

Table 3 Number (and proportion) of teachers agreeing with perspectives on the project-based learning approach in science education

Formulated statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
a. The PBLA comprises collaborative learning and group focus discussion both of which facilitates critical thinking, creativity and easy retention of science contents				16 (40) ¹	24 (60)	40 (100)
b. The PBLA embraces practical work, cooperative learning elements both of which equip learners with practical and team working skills		4 (10)	3 (7.5)	21 (52.5)	12 (30)	40 (100)
c. Through PBL, teachers and learners participate in developing improvised learning materials, and learners apply them to solve the problem of insufficient conventional materials that may be available	1 (2.5)	2 (5)	1 (2.5)	36 (90)		40 (100)
d. The poor implementation of PBL during science content delivery decreases the efficacy of the memory to store the contents permanently		5 (12.5)		20 (50)	15 (37.5)	40 (100)
e. Poor implementation of PBL negatively reduces learner's motivation and attention which in turn leads to poor understanding and retention of science contents			4 (10)	8 (20)	28 (70)	40 (100)
f. Insufficient teachers' workshops and pieces of training on teaching and learning approaches negatively affect the implementation of PBLA			5 (12.5)	18 (45.0)	17 (42.5)	40 (100)

Source: Primary data, 2021 ¹Percent in parenthesis

presented in Table 3 could be attributed to mindsets of instructors who are still holding traditional practices in the teaching and learning process therefore, they develop resistance to change in their working process.

Effect of the project-based learning approach on learners' conceptualization and achievement in science education

A major purpose of the research was to compare the effect of project-based learning approach to teaching and traditional method of teaching on learners' conceptualization and achievement in science education. To ascertain whether or not there was a significant difference between the means of the control and the experimental group, the scores of both groups in the pre and post tests were compared. Table 4 presents the

descriptive statistics for the control group and the experimental group respectively.

From Table 4, it can be observed that the control group in the pre-test had a mean of 10.8 (SD = 2.61) whereas the experimental group had a mean of 11.5 (SD = 2.09) indicating the two groups were comparable at the onset of the experiment. But after the treatment, the control group in the post-test had a mean of 10.5 and a standard deviation of 2.30 whereas in the experimental group had mean of 11.6 and a standard deviation of 2.26. Therefore, to check whether the difference was statistically significant, an independent sample t-test was used at 0.05 level of significance to test the hypothesis that "there exist no significant difference in conceptualization and achievement in science of learners' taught using PBL approach and those taught using normal traditional learning

Table 4 Descriptive statistics of the control and experimental group in the pretest and the post-test.

Test	Group	N	Mean	Std. Dev.
Pre-Test	Control	51	10.8	2.61
	Experimental	55	11.5	2.09
Post-Test	Control	51	10.5	2.30
	Experimental	55	11.6	2.26

Source: primary data, 2021

Table 5 Results of Independent sample t-test of students' means in the control and the experimental group in the pre and post-test

Test	Group	N	Mean	Std. Dev.	t	df	Sig
Pre-Test	Control	51	10.8	2.61	-1.599	104	.11
	Experimental	55	11.5	2.09			
Post-Test	Control	51	10.5	2.30	-2.463	104	.01
	Experimental	55	11.6	2.26			

approach". The result of the test is shown in Table 5.

The results of this test (Table 5) revealed that there was no statistically significant difference ($t=-1.599$; $p = .113$) in the mean scores between the control group and experimental group at the beginning of the experiment. Table 5 shows the learners in the experimental group, who were exposed to the PBL treatment, obtained a mean score ($M=11.6$, $SD=2.26$) which was higher than the mean of the learners in the control group ($M=10.5$, $SD=2.30$), indicating a statistically significant difference ($t=-2.463$; $p < .05$) in the mean scores of the control group and the experimental group at the end of the experiment.

Discussion of results

As it was thoughtfully indicated in the research objectives and research hypothesis, this study was carried out to investigate the effect of project learning on learners' academic performance. Researchers used quasi experimental design in order to compare the learning outcomes under different learning modalities. The results of this study showed that there were no statistically significant differences in the pretest scores among learners of control and experimental groups ($P \geq 0.05$) as stipulated above. This was done purposively to take into consideration previous knowledge and skills of learners during our investigation. The use of project learning approach was proven promising towards the improvement of learners' academic performance in science subject specifically Physics in the current study. Throughout rounds of teaching and learning activities, learners in the control and experimental groups received different treatment that is learning approach. With the reference to the results, learners in the experimental group performed better than those in control group during Physics Achievement Test administered ($P \leq 0.05$).

Views of secondary school science teachers were gathered in order to ensure their experience towards the use of project learning approach in teaching and learning process. Moreover, we also wanted to consider teachers' appreciation of project-based learning approach. The majority confirmed that project-based learning encompasses various advantages including but not limited to critical thinking, creativity and easy retention of science contents. More importantly, about 90% of teachers who participated in this study asserted that they work with learners to develop improvised learning materials during project-based learning. Additionally, they slightly asserted the lack of teachers' workshops and pieces of training on teaching and learning approaches significantly contributes to poor implementation of project-based learning approach, which in turn leads to loss of interest and motivation by learners.

Generally, this study indicated that projected-based learning approach is one of the promising learning approaches that could receive much attention in the field of education, particularly in science teaching and learning endeavors.

Conclusion and recommendations

Briefly, it is imperative to argue with the scientific community about the role of project-based learning approach in science education. Despite the confusions demonstrated by participants in this study, where some of them disagreed or remained neutral for some statements regarding the role of project-based learning approach, the current study exposed the unparalleled benefits linked to proper design and implementation of PBL in teaching and learning process. There is a positive effect in overall academic performance of learners in science subject when PBL is properly integrated into teaching and learning processes.

Due to vital and unique promising learning flexibility fashioned along with the proper implementation of PBLA, we suggest that preservice and in-service teachers may be trained in order to respond to the need of implementation of project-based learning approach in science education.

1. The successful implementation of PBL requires collaborative efforts of different educational bodies, in the case of Education system in Rwanda, NESA and MINEDUC are the most concerned bodies, they should work together to plan regular teachers' workshops and pieces of trainings on the implementation of PBL, and other teaching and learning approaches.
2. Head teachers and staff members should appreciate the benefits of using PBLA in the learning endeavors. Therefore, they should maximize their potential in creativity and innovation in academic related works
3. Learners are encouraged to engage in constructing their own knowledge and skills through project-based learning which in turn would be beneficial in their future undertakings.

Declaration of competing interest

Authors declares that there exists no competing interest regarding the content presented.

Acknowledgement

We thankfully acknowledge the financial support from the African Center of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS), University of Rwanda-College of Education. We also thankfully acknowledge the collaboration with secondary science teachers and learners from G.S Gihinga, Kayonza.

References

- Alfiyanti, I. F., & Jatmiko, B. (2020). The Effectiveness of Predict Observe Explain (POE) Model with PhET to Improve Critical Thinking Skills of Senior High School Students. *Studies in Learning and Teaching*, 1(2), 76-85.
- Ayaz, M. F., & Sekerci, H. (2015). The Effects of the Constructivist Learning Approach on Student's Academic Achievement: A Meta-Analysis Study. *Turkish Online Journal of Educational Technology-TOJET*, 14(4), 143-156.
- Baker, J. P., Goodboy, A. K., Bowman, N. D., & Wright, A. A. (2018). Does teaching with PowerPoint increase students' learning? A meta-analysis. *Computers & education*, 126, 376-387.
- Barak, M., & Yuan, S. (2021). A cultural perspective to project-based learning and the cultivation of innovative thinking. *Thinking Skills and Creativity*, 39, 100766.
- Choi, J., Lee, J.-H., & Kim, B. (2019). How does learner-centered education affect teacher self-efficacy? The case of project-based learning in Korea. *Teaching and teacher education*, 85, 45-57.
- Dignath, C., & Veenman, M. V. (2021). The role of direct strategy instruction and indirect activation of self-regulated learning—Evidence from classroom observation studies. *Educational Psychology Review*, 33(2), 489-533.
- Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International*

- Journal of Educational Research*, 102, 101586.
- Haryanto, P. C., & Arty, I. S. (2019). *The application of contextual teaching and learning in natural science to improve student's HOTS and self-efficacy*. Paper presented at the Journal of Physics: Conference Series.
- Hasanah, R. S., Sholihin, H., & Nugraha, I. (2021). An Investigation of Junior High School Students' Science Self-Efficacy and Its Correlation with Their Science Achievement in Different School Systems. *Journal of Science Learning*, 4(2), 192-202.
- Jamal, A.-H., & Tilchin, O. (2016). Teachers' accountability for adaptive project-based learning. *American Journal of Educational Research*, 4(5), 420-426.
- Kartini, F. S., Widodo, A., Winarno, N., & Astuti, L. (2021). Promoting Student's Problem-Solving Skills through STEM Project-Based Learning in Earth Layer and Disasters Topic. *Journal of Science Learning*, 4(3), 257-266.
- Latada, F., & Kassim, H. (2017). Problem-oriented project based learning (PoPBL): An initiative to encourage soft skills expansion among students at a public university. *Journal of Global Business and Social Entrepreneurship (GBSE)*, 1(3), 75-83.
- Lau, C., Kitsantas, A., Miller, A. D., & Rodgers, E. B. D. (2018). Perceived responsibility for learning, self-efficacy, and sources of self-efficacy in mathematics: a study of international baccalaureate primary years programme students. *Social Psychology of Education*, 21(3), 603-620.
- Morrison, J., Frost, J., Gotch, C., McDuffie, A. R., Austin, B., & French, B. (2020). Teachers' role in students' learning at a project-based STEM high school: Implications for teacher education. *International Journal of Science and Mathematics Education*, 1-21.
- Owens, A., & Hite, R. (2020). Enhancing student communication competencies in STEM using virtual global collaboration project based learning. *Research in Science & Technological Education*, 1-27.
- Pratama, D., Ranti, S., Usmeldi, U., & Syafriani, S. (2019). *Preliminary analysis of learners in developing student book oriented research based learning models using 3D pageflip professionals on science lessons junior high school*. Paper presented at the Journal of Physics: Conference Series.
- Ramdhani, M., Usodo, B., & Subanti, S. (2017). *Discovery learning with scientific approach on geometry*. Paper presented at the Journal of Physics: Conference Series.
- Rap, S., Feldman-Maggor, Y., Aviran, E., Shvarts-Serebro, I., Easa, E., Yonai, E., . . . Blonder, R. (2020). An applied research-based approach to support Chemistry teachers during the COVID-19 pandemic. *Journal of chemical education*, 97(9), 3278-3284.
- Regmi, K. (2012). A Review of Teaching Methods--Lecturing and Facilitation in Higher Education (HE): A Summary of the Published Evidence. *Journal of Effective Teaching*, 12(3), 61-76.
- Roberts, D. (2019). Higher education lectures: from passive to active learning via imagery? *Active Learning in Higher Education*, 20(1), 63-77.

- Santyasa, I. W., Rapi, N. K., & Sara, I. (2020). Project Based Learning and Academic Procrastination of Students in Learning Physics. *International Journal of Instruction*, 13(1), 489-508.
- Sasson, I., Yehuda, I., & Malkinson, N. (2018). Fostering the skills of critical thinking and question-posing in a project-based learning environment. *Thinking Skills and Creativity*, 29, 203-212.
- Shah, H. N., Patel, D. S., & Chhatrivala, M. N. (2021). Project-Based Learning, an Effective Tool for the Active Teaching-learning Method for First-year Medical Students. *Int J Cur Res Rev* | Vol, 13(10), 41.
- Sharma, A., & Kumar, N. (2018). Importance of Talk and Chalk Method of Teaching: Dental Students' view in Preclinical Years. *Int. J. HealthCare Edu. & Med. Inform*, 5(3).
- Sunarno, W. (2019). *The effect of project based learning on learning environment and learning outcomes in vocational high school students*. Paper presented at the Journal of Physics: Conference Series.
- Tsai, M.-N., Liao, Y.-F., Chang, Y.-L., & Chen, H.-C. (2020). A brainstorming flipped classroom approach for improving students' learning performance, motivation, teacher-student interaction and creativity in a civics education class. *Thinking Skills and Creativity*, 38, 100747.
- Twahirwa, J., & Twizeyimana, E. (2020). Effectiveness of Practical Work in Physics on Academic Performance among Learners at the selected secondary school in Rwanda. *African Journal of Educational Studies in Mathematics and Sciences*, 16(2), 97-108.
- Usmeldi, U. (2018). *The effectiveness of research-based physics learning module with predict-observe-explain strategies to improve the student's competence*. Paper presented at the Journal of Physics: Conference Series.
- Utami, B., Probosari, R., Saputro, S., & Masykuri, M. (2019). *Empowering critical thinking skills with problem solving in higher education*. Paper presented at the Journal of Physics: Conference Series.
- Vogler, J. S., Thompson, P., Davis, D. W., Mayfield, B. E., Finley, P. M., & Yasseri, D. (2018). The hard work of soft skills: augmenting the project-based learning experience with interdisciplinary teamwork. *Instructional Science*, 46(3), 457-488.
- Wang, S. (2017). "Teacher Centered Coaching": An Instructional Coaching Model. *Mid-Western Educational Researcher*, 29(1).
- Wurdinger, S., & Qureshi, M. (2015). Enhancing college students' life skills through project based learning. *Innovative Higher Education*, 40(3), 279-286.
- Zadok, Y. (2019). Project-based learning in robotics meets junior high school. *Journal of Engineering, Design and Technology*.
- Zhang, L. J., & Zhang, D. (2020). Dialogic discussion as a platform for constructing knowledge: Student-teachers' interaction patterns and strategies in learning to teach English. *Asian-Pacific Journal of Second and*

Appendices

Appendix I. Questionnaire for secondary school sciences teachers' questionnaire

1. The PBL comprises collaborative learning and group focus discussion both of which facilitates critical thinking, creativity and easy retention of science contents.

a) Strongly disagree b) Disagree c) Neutral d) Agree e) Strongly agree

2. The PBL embraces practical work, cooperative learning elements both of which equip learners with practical and team working skills.

a) Strongly disagree b) Disagree c) Neutral d) Agree e) Strongly agree

3. Through PBL, teachers and learners participate in developing improvised learning materials, and learners apply them to solve the problem of insufficient conventional materials that may be available.

a) Strongly disagree b) Disagree c) Neutral d) Agree e) Strongly agree

4. The poor implementation of PBL during science content delivery decreases the efficacy of the memory to store the contents permanently.

a) Strongly disagree b) Disagree c) Neutral d) Agree e) Strongly agree

5. The poor implementation of PBL negatively reduces learners' motivation and attention, which in turn leads to poor understanding and retention of science contents

a) Strongly disagree b) Disagree c) Neutral d) Agree e) Strongly agree

6. Insufficient teachers' workshops and pieces of training on teaching and learning approaches negatively affect the implementation of PBLA

a) Strongly disagree b) Disagree c) Neutral d) Agree e) Strongly agree

Appendix II. Physics Achievement Test administered among senior learners

Questions were prepared by using Rwandan Competency-Based Curriculum (CBC) from unit 9 entitled "Heat and temperature"

1. The joule(j) is international unit of

a) Power b) Heat c) Temperature d) No response

2. which one of following corresponds to the process by which liquid is converted to vapour in the presence of constant temperature.

a) Melting b) Boiling c) Both boiling and melting d) No response

3. Among the thermometers below, which one can be used to measure individual body temperature.

- a) Both maximum and minimum thermometers b) Clinical thermometer c) Alcohol-in-glass thermometer
d) No response
4. What is another name of thermal imaging instrument.
a) Thermometer b) Infra-red c) Calorimeter d) No response
5. Which one among the laboratory thermometers utilizes only coloured alcohol.
a) Mercury-in-glass thermometer b) Alcohol-in-glass thermometer c) Maximum thermometer
d) No response
6. Which one among the thermometers that has a space on the top of mercury that stops the excess of pressure in case of expansion in mercury.
a) clinical thermometer b) Mercury-in-glass thermometer c) Minimum thermometer d) No response
7. Which of the following instrument is used to measure heat. a) Calorimeter b) Thermal imaging instrument c) Thermometer d) No response
8. The international unit of temperature is
- a) Celsius b) Kelvin c) Joule d) No response
9. The following are types of temperature scale except.
a) Kelvin scale b) Energy scale c) Celsius scale d) Fahrenheit and Reaumur scale
10. Which one among the listed values correspond to the lower fixed points of the Celsius scale.
a) 100 °C b) 0 °C c) -27 °C d) No response
11. The following are the roles of alcohol as a thermometric liquid except.
a) Alcohol is cheap and available easily b) Alcohol is a bad thermal conductor c) Alcohol has a bright colour d) No response
12. Which one among the listed values correspond to the upper fixed points of the Celsius scale.
a) 273 °C b) 100 °C c) 1 °C d) No response
13. The following are the roles of mercury except.
a) Mercury has the capacity to move heat energy easily b) Mercury expand non-uniformly
c) Mercury is opaque fluid or liquid d) No response
14. Among the listed values, which one correspond to the absolute zero of the Kevin scale.
a) + 273 °C b) – 273 °C c) 32 °C d) No response
15. which one among the listed values correspond to the boiling point of water in the Fahrenheit scale.
a) 213 °F b) 212 °F c) 274 °F d) No response

16. How do we call the interval between upper fixed point and lower fixed point for the Fahrenheit scale.

- a) Fixed interval b) Fundamental intervals c) Spacing intervals d) No response

17. Which one is not true among the thermometric properties listed below.

- a) The property must remain constant when there is no change in temperature
 b) The property must have a small change when there is a small change in temperature.
 c) There should be uniform change in the property when there is a change in temperature
 d) No response

18. From the listed values below, select the separation value between lower fixed point and upper fixed point.

- a) 185 °F b) 180 °F c) 182 °F d) No response

19. can be defined as a state obtained in two substances, which are in thermal conduct without transfer of heat among them.

- a) Thermal non-equilibrium b) Thermal equilibrium c) Thermal substance d) No response

20. Which one among the listed values below correspond to the freezing of water in Reaumur scale.

- a) 80 °F b) 0 °F c) 1 °F d) No response

Appendix III Experimental group learners under treatment during investigation

S/N& Lesson title		Learning methods/Materials	Learners' activities
		Different forms of project-based learning approach	<ul style="list-style-type: none"> Followed the guidance and instructions provided by the facilitator. Formed small groups by taking into consideration learners' performance, gender and intellectual capacities for the sake of helping each other in the group. Observed both instruments used to measure heat & temperature and discuss their daily application through groups. Each group selected one learner to explain and present their findings after measuring both heat & temperature while others follow and actively ask where needs clarification. One learner was pick randomly by the facilitator to summarize the lesson. Recorded notes in their notebook.
1	Contrast heat & temperature	Experimentation methods Guided inquiry-based learning, learning by doing Group discussion Presentation	
	Temperature scale	Problem solving method, cooperative method, exploratory method, small group discussion, Self and guided directed learning	

3	Melting & boiling point of substance	Experimentation methods, self-observation, discovery learning, learning by doing, demonstration methods, interactive methods, group presentation.	<ul style="list-style-type: none"> • Formed small groups, at least each having 3 to 4 learners. • Dispatched problem-solving tasks to each group for discussion and sharing views. • Learners consulted elders, teachers and interacted with different textbooks, YouTube and Google using connected laptops with wireless. • Each shared the results to the nearest group to evaluate and comments on the work done. • Each group addressed the comments given and recorded what they shared in the notebook as a note. • Wrote the individual homework from the Rwandan competence based-curriculum, S1 learners' textbook, page 266, exercise 9.1. • Formed small groups respecting intellectual capacities and gender. • Discussed the names of the laboratory apparatus and their real-life application in the groups. • Performed the experiments to indicate the melting and boiling of the substance. • Learners participated and engaged actively during discussion and presentation. • Each group selected a representing learner to share with the entire learners their findings from the experiments as a group. • Different concerns were raised during the presentation period for better understanding lesson.
Teacher's guidance			
<p>Ensured that environment is academically conducive.</p> <p>Provided the instructions, tasks and all the necessary learning materials /resources.</p> <p>Moved around the groups intentionally looking how learners are interacting and responds to individual learner's concerns.</p> <p>Asked challenging questions during presentation to see whether all group members have understood what they have learnt.</p> <p>Giving suggestions and correcting mistakes made during presentation.</p>			
Teacher's self-evaluation			

The learning objectives were achieved for the first and third lessons while partially achieved for the second lesson following the failure observed among five learners during a homework activity. Therefore, a remedial session will be conducted to help these learners achieve the learning objectives.

Source: Author's elaboration based on Rwanda Secondary Education Curriculum