MULTIDISCIPLINARY SCIENCE JOURNAL

RESEARCH ARTICLE
Published Online: November 15, 2025
https://doi.org/10.31893/multiscience.2026358

Problem-based learning-integrated Kasongan Pottery Ethno-STEM to increase elementary school students' concept mastery of science: A case study from Indonesia

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Abstract This research aims to know the effect of problem-based learning-integrated Kasongan pottery ethno-STEM on improving elementary school students' concept mastery of science in Bantul, Yogyakarta, Indonesia, particularly in the areas of heat and heat transfer. This study employs a quantitative approach via a quasii-experimental method. The research design is a pretest-posttest nonequivalent control group design. In this case, the pretest is administered at the initial stage (when elementary school students have not yet received the treatment), whereas the posttest is administered after the students have received the treatment. The experimental class was given problem-based learning-integrated Kasongan pottery ethno-STEM. The control class was given conventional learning, such as problem-based learning. The sample in this study consists of 54 elementary school students from SD N Kasongan, Bantul, Yogyakarta, Indonesia, who are currently enrolled in science classes. Moreover, a multiple-choice concept mastery instrument was used to measure concept mastery before and after teaching about heat and heat transfer via problem-based learning-integrated Kasongan pottery ethno-STEM. The data analysis techniques used in this study were performed via inferential statistics (univariate independent sampel t-test analysis); with a significance level of 0.05. The results revealed a significant difference in the scores for conceptual mastery improvement between the experimental class and the control class. The average score for conceptual mastery improvement in the experimental class was 0.59; with a standard deviation of 0.56, whereas the average score for conceptual mastery improvement in the control class was 0.11; with a standard deviation of 0.59. On the basis of the t-test results, the sig. value was obtained 0.004 < 0.05, it can be concluded that there is a significant difference in concept mastery improvement between the experimental class and the control class. The average concept mastery improvement score of the experimental class was 0.48 higher than that of the control class. Thus, problem-based learning-integrated Kasongan pottery ethno-STEM can significantly improve elementary school students' concept mastery of science.

Keywords: problem-based learning, Kasongan pottery ethno-STEM, elementary school, concept mastery

1. Introduction

Learning in elementary schools focuses on knowledge that is built in students' minds, where the knowledge obtained is the result of students' own construction or active and independent formation, which is influenced by their sociocultural conditions. Thus, cognitive development becomes the result of a student's interaction with the environment and society. Learning involves students' interactions with the social and physical environment (Poedjiadi, 2019). Students can also learn meaningfully. They can construct something that is learned; and then associate experiences, new facts, and phenomena into a pre-existing understanding system. The learning process also places students in a central position (Savery, 2018). On the basis of this explanation, learning must be connected to the concepts that students have previously had, so that new concepts can be absorbed properly. Under these conditions, they need a learning model that involves contextual problems, thus encouraging students to learn independently, namely, problem-based learning (PBL) (Fakhriyah, 2014). They are also trained to solve problems armed with knowledge and experience (Joyce and Weill, 1980: 245).

The contextual problem given in PBL is something that students find in life, for example, the making of pottery in Kasongan, Bantul, Yogyakarta, Indonesia. Through this ethnoscience example, students are invited to solve the problem, namely, by analysing the manufacturing process scientifically so that they know that the resulting pottery can be explained

Received: August 20, 2025 | Accepted: October 21, 2025

with science subject matter. Local wisdom contains science concepts and can be explained with the science learned at school (Arfianawati et al., 2016; Sumarni et al., 2016; Suastra et al., 2021).

PBL can increase learning achievement and concept mastery through the experiences or real daily events of elementary school students. Activities carried out by teachers with students in the implementation of PBL must be carried out in accordance with the design of PBL implementation activities called syntax (Arends & Kilcher, 2010). This syntax, according to Arends (2001), involves a) orienting students to the problem, (b) organising students to learn, (c) guiding independent and group investigations, (d) developing and presenting work, and (e) analysing and evaluating the problem-solving process. On the basis of some of these stages, syntax can be developed by integrating other approaches to maximise the use of PBL in learning.

An approach that can be integrated into PBL is STEM. STEM provides opportunities for students to learn in an integrated manner rather than studying fragmented pieces (Dugger, 2015; Mpofu, 2019). The aspects of STEM are science, technology, engineering, and mathematics. In addition to these four areas, STEM can also foster soft skills such as scientific enquiry and problem-solving skills. This relates to PBL, where students are trained and familiarise with scientific enquiry and problem-solving skills. The STEM approach in PBL aims to equip students with skills and understanding in the four interrelated aspects of STEM. Students are also expected to be able to apply what they have learned in the real world (Kelley and Knowles, 2016).

In addition to the STEM approach, ethnoscience is integrated into the syntax of integrated ethno-STEM PBL (Kamila & Wilujeng, 2024). The emergence of ethnoscience cannot be separated from trial and error as a scientific method applied in ancient times (Sudarmin, 2015). Ethnoscience refers to local knowledge or the knowledge of indigenous peoples, so ethnoscience is an activity that transforms or reconstructs the knowledge of communities passed down from generation to generation into scientific knowledge (Rahayu and Sudarmin, 2015). Bantul ethnoscience integrated into the syntax of integrated ethno-STEM PBL involves pottery. Ethnoscience is used as a problem to analyse in science education on the topic of heat transfer, so that it can be explained via heat transfer concepts. The integration of ethnoscience in integrated ethno-STEM PBL is expected to help students understand that the pottery-making process can be explained through the use of science in science education.

Pottery generation involves heat and heat transfer (conduction, convection, and radiation) (Hani'ah, 2018). When pottery is fired in a kiln, heat (high temperature) from straw, wood, bark, or other combustible materials (fuel) is transferred to the pottery, which still has a low temperature. At this point, heat is transferred from the higher-temperature straw to the lower-temperature pottery. The right temperature is essential in the pottery firing process to produce sturdy, high-quality pottery that is not prone to cracking (Fatimah, 2016). Heat transfer is also an important concept in the pottery-making process, especially during the drying and firing stages. During the drying process, the pottery is dried under the sun, so there is the concept of heat transfer by radiation. The sun's rays emit heat directly to the pottery without any intermediary. Heat transfer by conduction occurs during the firing process of pottery in a kiln. This is because the flames from burning straw, wood, husks, or other fuels transfer heat to the pottery arranged inside the kiln, but there is no transfer of particles. Moreover, heat transfer by convection occurs during the firing process of pottery. Convective heat transfer during pottery firing occurs because hot air or steam from the kiln rises upwards around the pottery, replacing the cooler air that descends. This creates an air circulation that carries heat to the surface of the pottery, resulting in even and efficient firing.

Integrating ethnoscience and STEM (ethno-STEM) Kasongan pottery into science education can make it easier for students to understand science. For example, in the process of making pottery and drying pottery, students can be taught about heat transfer via radiation. Students can also learn about substances and their changes. This approach is a strategy for creating an ethnoscience learning environment and learning with cultural integration in science education (Puspasari et al., 2019; Idrus, 2022; Hidayati & Julianto, 2025). In addition, ethno-STEM also supports students in continuously increasing their knowledge through the culture that develops around them and is in line with the times.

Integrated ethno-STEM PBL is believed to help students develop their competencies, where they practice developing the science and technology they have learned. Students can increase their mastery of knowledge (content) and develop the visibility of technology and engineering/design, which provides a context for students to test their scientific knowledge development and apply it. Through integrated ethno-STEM PBL, students can learn science in a contextual manner that is relevant to their daily lives and local wisdom in Bantul. Students also practise understanding the simple technologies used in indigenous science and are able to produce simple designs to replace indigenous science technologies.

The production of Kasongan pottery in Bantul, Yogyakarta, can be examined from the aspects of ethno-STEM (science, technology, engineering, and mathematics), a) the science aspect, namely, the concepts of substance change, heat, and heat transfer,; b) the technology aspect, which involves the process of making pottery via technology, such as soil mixers, pottery wheels/molds, kilns, and marketing through websites and social media,; c) the engineering aspect, which involves the use of tools and pottery design,; and d) the mathematic aspect, which involves comparisons of the composition, size, firing temperature, and production time of pottery.

Integrated ethno-STEM PBL is also believed to develop a range of 21st-century skills and strengthen national identity. All of these aims to balance 'science for scientists' and 'science for life.' Thus, the integrated ethno-STEM PBL model is a new learning model as an alternative solution to existing science education models and can complement previously established science education models.

Moreover, problem-based learning-integrated Kasongan pottery ethno-STEM has several syntaxes,; a) orienting students to ethno-STEM issues related to Kasongan pottery in everyday life,; b) organising students to learn and study various materials related to Kasongan pottery ethno-STEM in the surrounding environment,; c) guiding independent and group investigations guided by LKPD (student worksheet) and teaching materials related to Kasongan pottery ethno-STEM,; d) developing and presenting learning outcomes related to Kasongan pottery ethno-STEM,; and e) analysing and evaluating the problem-solving process related to Kasongan pottery ethno-STEM.

Integrated ethno-STEM PBL can increase students' potential in the learning process. Students' potential can also be developed through learning, one of which is by improving their concept mastery. Concept mastery is defined as the process through which learners comprehend certain concepts (Fikriyah et al., 2020). In learning, concept mastery is considered important and indispensable. Concept mastery is an ability that enables students to understand concepts, facts, and situations, and explain them using their own words (Purwanto, 2010). Concept mastery is also a measure of learning success. This is because students face various problems that require solutions to link problem solving and concept mastery (Ejin, 2017). With concept mastery, students can construct understanding from a variety of concepts that they previously had (Arends, 2008). Concept mastery should be a concern in science learning rather than only memorisation. In this case, elementary school teachers must reach concept mastery because they use it when they teach in class (Nugroho & Suryadarma, 2018).

Concept mastery is an understanding, not only to remember the concepts learned, but also to be able to be re-expressed in the form of their own words, without changing the meaning. The concepts learned are influenced by age, language development, and the level of intellectual development. This is in accordance with the theory of cognitive development by Jean Piaget in relation to the concept of thinking (Dahar, 2016). Through concept mastery, students can construct understanding from previously owned concepts (Arends, 2008).

Unfortunately, on the basis of the results of research conducted by Purwanto (2010), students' concept mastery is still low. Students' awareness of following learning is still considered low, and students are less involved during the learning process, as happened at the elementary school in Bantul (Sulistianingsih, 2014). In addition, science learning outcomes are low compared with those of other subjects, especially in elementary school, especially in Bantul, Yogyakarta (Richana & Masithoh, 2023). This is due to several factors, including teachers only applying conventional learning models, via the lecture method. The lecture method does not involve students in active learning (Ester et al., 2023). This condition results in low concept mastery.

A poor understanding of concepts can result in the failure to achieve the objectives of science education itself (Purwanto, 2010). Learning is teacher-centred, and knowledge-transfer oriented, and students tend to memorise. Students learn facts and concepts verbally but are not trained to discover or process information. Learning science through memorisation causes students to learn science only at the 'to know' stage, not yet reaching the 'to do' stage (Duruka et al., 2017). Therefore, concept mastery must be developed properly (Fikriyah et al., 2020) because it is essential in the learning process (Prabowo et al., 2020). In this case, problem-based learning-integrated Kasongan pottery ethno-STEM can be used to increase elementary school students' concept mastery of science.

2. Materials and Methods

This study is a quantitative study that uses a quasii-experimental method (Hastjarjo, 2019). The research design is a pretest-posttest nonequivalent control group. The pretest was administered before the treatment, whereas the posttest was administered after the treatment (Rohmatulloh and Winarni, 2015). In this study, experimental and control classes were used. Learning in the experimental class took the form of problem-based learning-integrated Kasongan pottery ethno-STEM, whereas the control class used problem-based learning. The research design is shown in Table 1.

Table 1 Research design.

Group	Pretest	Treatment	Posttest
Experiment	O	X_1	O
Control	O	X_2	O

Information: O = concept mastery of science test. X_1 = problem-based learning-integrated Kasongan pottery ethno-STEM. X_2 = problem-based learning

This research was carried out in Yogyakarta, Indonesia, in the odd semester of the 2024-2025 academic year. This research takes place from April to May 2025. The sample for this research included 72 elementary school students, fourth grade, at SD N Kasongan, Bantul, Yogyakarta, Indonesia, who were taking science as their subject. Randomization of the sample was carried out based on the location of the school closest to the Kasongan pottery craft center, and the school also conducted science learning using Kasongan pottery as a teaching aid, and there was also a practice of making Kasongan pottery at the school. The technique used in this research to collect data is test (multiple choice).

3. Results

This research aims to measure significant differences in the concept mastery of science before and after substance change and heat transfer are taught with problem-based learning-integrated Kasongan pottery ethno-STEM and problem-based learning.

3.1. Descriptives

To make it easier to analyse the data in this study, refer to Table 2, which explains the experimental group and control group.

Table 2 Descriptives.

	Group			Statistic	Std. Error
N-gain	Experimental	Mean		0.5878	0.10867
		95% Confidence Interval for Mean	Lower Bound	0.3645	
			Upper Bound	0.8112	
		5% Trimmed Mean		0.597	
		Median		0.6138	
		Variance		0.319	
		Std. Deviation		0.56466	
		Minimum		-0.8	
		Maximum		1.71	
		Range		2.51	
		Interquartile Range		0.5	
		Skewness		-0.074	0.448
		Kurtosis		0.566	0.872
	Group			Statistic	Std. Error
N-gain	Control	Mean		0.1123	0.1142
		95% Confidence Interval for Mean		Lower Bound	
				Upper Bound	
		5% Trimmed Mean		0.1281	
		Median		0.1796	
		Variance		0.352	
		Std. Deviation		0.59338	
		Minimum		-1.12	
		Maximum		1.05	
		Range		2.17	
		Interquartile Range		0.86	
		Skewness		-0.452	0.448
		Kurtosis		-0.279	0.872

3.2. T-test steps

3.2.1. Normality test

3.2.1.1. Hypothesis

3.2.1.1.1. Experimental group

H_0: n-gain data in the sample come from a normally distributed population.
H_1: n-gain data in the sample come from a nonnormally distributed population.

3.2.1.1.2. Control group

H_0: n-gain data in the sample come from a normally distributed population.
H_1: The n-gain data in the sample come from a population that is not normally distributed.

3.2.2. Significance level

$\alpha = 5\% = 0.05$.

3.2.3. Acceptance criteria

H_0 is accepted if sig $\geq \alpha$.
H_0 is rejected if sig $< \alpha$.

3.2.4. SPSS output

3.2.4.1. Experimental group

The sig. value (according to both the Kolmogorov-Smirnov test (0.074) and the Shapiro-Wilk test (0.374)) is greater than α = 5% = 0.05, so H_0 is accepted.

3.2.4.2. Control group

The sig. value (according to both the Kolmogorov-Smirnov test (0.200) and the Shapiro-Wilk test (0.445)) are greater than α, so H_0 is accepted.

3.2.5. Conclusion

The n-gain data in the experimental and control group samples come from a normally distributed population.

3.2.5.1. Homogeneity test

3.2.5.1.1. Hypothesis

H_0: $\sigma_1^2 = \sigma_2^2$ (the experimental and control populations have homogeneous variances).

H_1: $\sigma_1^2 = \sigma_2^2$ (the experimental and control populations have homogeneous variances).

3.2.5.1.2. Significance level

α = 5% = 0.05.

3.2.5.1.3. Acceptance criteria

H_0 is accepted if sig ≥ α.
H_0 is rejected if sig < α.

3.2.6. SPSS Output

Explanation: The sig value (in the row based on the mean) obtained is 0.512, which is greater than α, so H_0 is accepted.

3.2.7. Conclusion

The two groups, the experimental and control populations, had homogeneous variances.

3.3. T-test

3.3.1. Hypothesis

H_0: There is no significant difference in the concept mastery of science between elementary school students with problem-based learning-integrated Kasongan pottery ethno-STEM and those with problem-based learning.

H_1: There is a significant difference in the concept mastery of science between elementary school students with problem-based learning-integrated Kasongan pottery ethno-STEM and those with problem-based learning.

3.3.2. Significance level

α = 5% = 0.05.

3.3.3. Acceptance criteria

H_0 is accepted if sig $\geq \alpha$.
H_0 is rejected if sig $< \alpha$.

3.3.4. SPSS output

Explanation: The sig value (in the row "equal variances assumed") obtained is 0.004, which is smaller than α = 5% = 0.05, so H_0 is rejected (H_1 is accepted).

3.3.5. Conclusion

There is a significant difference in the concept mastery of science between elementary school students with problem-based learning-integrated Kasongan pottery ethno-STEM and those with problem-based learning.

4. Discussion

This research involved the experimental class and the control class. Learning in the experimental class took the form of problem-based learning-integrated Kasongan pottery ethno-STEM, whereas the control class used problem-based learning. To test the significance of the difference between students who took the form of problem-based learning-integrated Kasongan pottery ethno-STEM and students who took the form of problem-based learning in terms of improving their concept mastery of science, a statistical test was conducted using t-test. To show t-test, the prerequisites of normality and homogeneity are required. The normality test was conducted using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The test results showed that in the experimental group, the significance values (according to the Kolmogorov-Smirnov test (0.074) and the Shapiro-Wilk test (0.374)) was greater than a = 5% = 0.05, so it can be concluded that the experimental group sample came from a normally distributed population (Table 3). Moreover, in the control group, the significance values (according to the Kolmogorov-Smirnov test (0.200) and the Shapiro-Wilk test (0.445)) was greater than a = 5% = 0.05, so it can be concluded that the control group sample came from a normally distributed population. Thus, the n-gain data in the experimental group and the control group samples come from a normally distributed population. The test of homogeneity of variance (Levene statistic) was used to test homogeneity. The test results show that the significance values is greater than a = 5% = 0.05, so it can be concluded that the two population groups (the experimental group and the control group) have homogeneous variances (Table 4).

Table 3 Test of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests).

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	df	Sig.
N-gain	Experimental	.160	27	.074	.960	27	.374
	Control	.111	27	.200*	.964	27	.445

a. Lilliefors Significance Correction. *. This is a lower bound of the true significance.

Table 4 Test of homogeneity of variance (Levene statistic).

		Levene Statistic	df1	df2	Sig.
N-gain	Based on mean	.436	1	52	.512
	Based on median	.397	1	52	.531
	Based on median and with adjusted df	.397	1	51.718	.531
	Based on trimmed mean	.425	1	52	.518

If the prerequisites for normality and homogeneity in the t-test have been met, so the t-test can be conducted with an independent sample t-test. A significance value of 0.004 was obtained via the t-test, which is smaller than α = 5% = 0.05, so it can be concluded that there is a significant difference in concept mastery of science between students in the experimental class and students in the control class (Table 5). This indicates that the experimental class showed greater improvement than the control class because the average score of the experimental class was higher than the control class. The n-gain of the experimental class (with an average of 0.5878) was higher than the n-gain of the control class (with an average of 0.1123). This can be observed in Figure 1-2. On the basis of the t-test, the experimental class differs significantly from the control class, so it can be concluded that problem-based learning- integrated Kasongan pottery ethno-STEM can improve elementary school students' concept mastery of science.

Table 5 Independent sample t-test.

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
N-gain	Equal variances assumed	.436	.512	3.016	52	.004	.47550	.15764	.15917	.79182
	Equal variances not assumed			3.016	51.873	.004	.47550	.15764	.15915	.79184

The results of this research, which applied problem-based learning-integrated Kasongan pottery ethno-STEM in science learning, provide an effective solution to the limitations of other conventional teaching methods, such as problem-based learning, in improving elementary school students' concept mastery of science. As revealed by the research findings of Richana

& Masithoh (2023), science learning outcomes are relatively low compared to other subjects, particularly at the elementary school level, especially in Bantul, Yogyakarta, Indonesia. Low learning outcome is partly due to the low concept mastery of science among elementary school students, as reported in the research findings of Purwanto (2010). Low concepts mastery of science also leads to students being less active in science learning, as observed among elementary school students in Bantul, Yogyakarta, Indonesia (Sulistianingsih, 2014). Therefore, to improve students' learning outcomes and their active participation in science learning, students' concepts mastery of science must also be enhanced by implementing problem-based learning-integrated Kasongan pottery etno-STEM. The application of STEM in learning can encourage students to design, develop, and utilize technology, hone cognitive, manipulative, and affective skills, and apply knowledge (Kapila & Iskander, 2014). A meta-analysis revealed that the implementation of ethnoscience-integrated STEM (ethno-STEM) in Indonesia involved 23.07% of experimental research. Most ethno-STEM-based experimental research articles tested the effectiveness of using ethno-STEM integrated learning models (Idrus, 2022). The results of this study indicate that the ethno-STEM approach is very effective in the learning process (Azalia, 2020). The implementation of STEM is important because the results of the 2012 PISA assessment showed that scientific, language (reading), and mathematical literacy among Indonesian students are currently relatively low. These results are certainly different from the 2012 PISA assessment of China, which had the highest score. Therefore, the implementation of STEM is considered suitable and appropriate for use in science learning, especially to improve students' mastery of concepts and student learning outcomes (Permanasari, 2016).

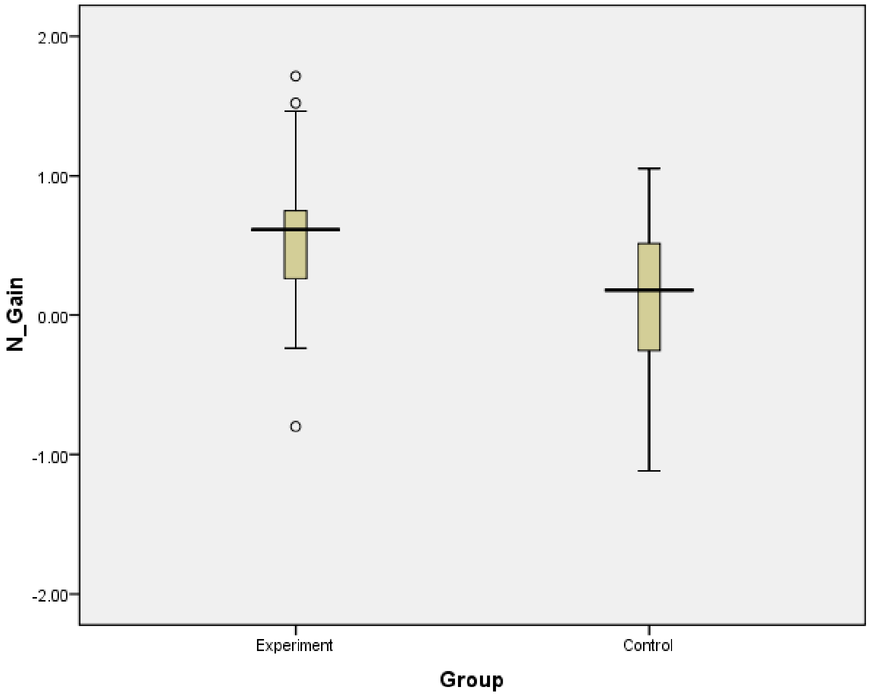

Figure 1 Box plot n-gain of experimental and control classes.

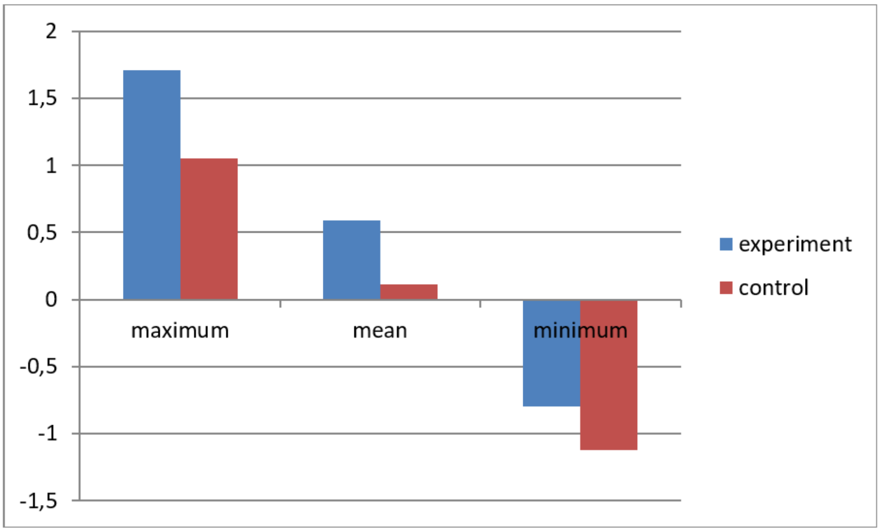

Figure 2 Graph of maximum, minimum, and average values of the experimental and control classes.

The results of this study also controlled for confounding variables, such as differences in student characteristics and motivation levels. Control for confounding variables was achieved through randomization and restriction. Randomization involved randomly assigning students to several groups to minimize differences in characteristics, while restriction limited the research sample to specific groups to eliminate the influence of confounding variables.

The results of this study also align with the constructivist learning theory framework (constructivism theory) proposed by Jean Piaget, Jerome Brunner, John Dewey, Lev Vygotsky, and David Paul Ausubel. Piaget's theory focuses on how individuals create meaning through the interaction between their experiences and their ideas, while social interactions act as a stimulus for internal cognitive conflict within individuals. Jerome Bruner shared a similar view with Jean Piaget regarding the process of acquiring knowledge: that in acquiring knowledge, individuals filter information before ultimately accepting the new knowledge (Habsy et al., 2023). According to Brunner, cognitive development occurs through three cognitive processes: acquiring new information, transforming knowledge, and evaluating (Budiyanti et al., 2023). Contrary to John Dewey's constructivist theory, in the learning process, teachers present various experimental problems encountered in school, while students solve them. Meanwhile, Vygotsky's theory explains that teachers must facilitate students' collaboration with peers who are more competent than them. When students experience learning difficulties, teachers must act as guides and facilitators. The implications of Ausubel's theory in learning include the need to provide advanced material to link previous material with new material to be learned, material is presented from the general to the specific, and material is presented from the simple to the complex (Dayanty, 2021). The constructivist theory of several figures is in accordance with the results of this study because it focuses on the active role of students in generating knowledge through experiences in interacting with the environment, especially linking scientific concepts in the stages of making Kasongan pottery crafts that are in accordance with STEM (science, technology, engineering, and mathematics) aspects. This study also emphasizes the importance of social interaction and collaboration, so that students will more easily understand difficult concepts if they discuss with their group mates and are guided by the teacher. In addition, this study involves learning that is connected to the real life of children in the surrounding environment, which is closely related to cultural elements, namely Kasongan pottery crafts, Bantul, Indonesia.

5. Conclusions

On the basis of the results of the analysis and discussion, it can be concluded that problem-based learning-integrated Kasongan pottery ethno-STEM has an effect on increasing the concept mastery of science. This finding supports the skills of elementary school students in transferring their knowledge to other concepts; so that their overall competence increases. Furthermore, they also show increased learning outcomes and are more accomplished. They are expected to keep up with the times and concept mastery of science taught (by improving their conceptual understanding); without forgetting the noble culture of the Indonesian people (local wisdom), such as Kasongan pottery, in Bantul, Yogyakarta, Indonesia.

Acknowledgement

The authors would like to thank SD N Kasongan and Yogyakarta State University, which supported this research. Without that support, this research would not have been possible.

Ethical considerations

In terms of ethical considerations, the data collection and experiments were approved by SD N Kasongan and Universitas Negeri Yogyakarta. This research was conducted based on ethical procedures regarding participant consent at SD N Kasongan, as evidenced by the existence of a research permit letter from the Principal of SD N Kasongan, the fourth-grade science teacher at SD N Kasongan, and consent from the participants (fourth-grade students). Elementary school students (participants) agreed to participate in free-will and were conducted in the presence of teachers. Teachers have also received prior training in implementing problem-based learning-integrated Kasongan pottery ethno-STEM, so that consistency in delivering interventions can be ensured. This research has also received approval from Universitas Negeri Yogyakarta, as evidenced by a research permit.

Conflict of interest

The authors declare that they have no conflicts of interest.

Funding

This research did not receive any financial support.

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