

An Integrative Learning Model to Improve Problem-Solving and Creative Thinking Abilities, Collaboration, and Motivation

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Abstract

Various empirical research show that the ability to problem-solving, creative thinking, collaboration, and motivation to learn mathematics in Indonesia is relatively low. This research aims to develop a project-based mathematics learning model integrated with ethnomathematics and technology. Furthermore, this research also aims to determine the feasibility, practicality, and effectiveness of the developed model in improving problem-solving skills, creative thinking, collaboration, and motivation to learn mathematics. This research approach is Research and Development (RnD), which refers to the Borg and Gall model. The level of validity of models, learning tools, and assessment instruments is proven through the Aiken validity index. The model's practicality was analyzed based on the results of observations of product implementation and student responses. Meanwhile, the model's effectiveness was analyzed using the t-test, One-Way MANOVA, and n-gain. Based on the results of proving the model's validity, the Aiken validity index is .88, and the estimated reliability coefficient is .76, indicating that the developed model meets the valid and reliable criteria. Furthermore, based on the results of the observational analysis of the implementation of the model at the main field-testing stage, the practicality rate of the model was 88% (very practical), and the rate of student responses was 73% (practical). Multivariate and univariate test results show that project-based learning models integrated with ethnomathematics and technology effectively improve problem-solving skills, creative thinking, collaboration, and learning motivation. The project type and the variables measured number are the this research novelty. These research findings can be reference material and alternative solutions for teachers in designing a new learning culture and improving the learning quality.

INTRODUCTION

Various educational problems still occur in Indonesia, especially during the Covid-19 pandemic. The low achievement of students was the aspect that was most highlighted in the education system in Indonesia, even before the covid pandemic hit Indonesia in March 2020. The learning achievements of students in Indonesia are not yet optimal, as evidenced by the low average score on the national examination in all subjects tested, including mathematics. Data shows that the mathematics average score in the last four years is below 40.00 out of 100.00 and the lowest of all subjects in the national exam (Pusat Penilaian Pendidikan, 2019).

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In addition, (Prabowo, 2018; Sumaryanta et al., 2019) found that the majority of students experienced difficulties in all the mathematics material tested.

Based on a survey from the Trends International Mathematics and Science Study (TIMSS) in 2015, Indonesian students' mathematical ability was ranked 44 out of 50 countries (Mullis et al., 2016). Furthermore, when assessed using PISA in 2018, Indonesian students' mathematics learning achievement was also low and even decreased compared to PISA in 2015 (OECD, 2016, 2019). TIMSS reports in 2011 (Mullis et al., 2016; Mullis et al., 2012) showed that less than 5% of students in Indonesia could work on high and advanced-type questions. Both types of questions require mathematical creative thinking abilities. The 2015 and 2018 PISA results also show that Indonesian students' mathematical creative thinking skills are still deficient (OECD, 2016, 2019). This result is proved by the low percentage of students in Indonesia who are able to solve mathematical problems of the high-order thinking type, where problem-solving abilities and mathematical creative thinking abilities are needed.

Based on the problems above, it is necessary to develop a new mathematics learning model to improve the quality of mathematics learning in Indonesia. This research develops project-based mathematics learning integrated with ethnomathematics and technology. The project learning model involves students completing specific projects through a constructive inquiry process and is completed collaboratively according to the real world (Bell, 2010; Pearlman & Thomas, 2000). Several previous studies found that the project-based learning model is able to provide positive results in improving problem-solving abilities (Chiang & Lee, 2016; Koutrouba & Karageorgou, 2013), creative thinking abilities (Bell, 2010; Koutrouba & Karageorgou, 2013; Pratama et al., 2023; Xu & Liu, 2010), collaboration abilities (Bell, 2010; Koutrouba & Karageorgou, 2013; Maija & Haatainen, 2019; Verner et al., 2013; Xu & Liu, 2010) and motivation students' learning (Chiang & Lee, 2016; Holmes & Hwang, 2016; Mahendra, 2017; Maija & Haatainen, 2019; Terrón-López et al., 2017).

In particular, this integrative learning model was developed to improve problem-solving abilities, creative thinking, collaboration, and motivation to learn mathematics because many students' problem-solving skills are relatively low (Hadi et al., 2018; Retnawati et al., 2017). The creative thinking abilities of most Indonesian students are also still low based on TIMSS reports in 2011 and 2015, as well as the results of PISA in 2015 and 2018. The collaboration abilities of students in Indonesia are also not optimal (Aliftika et al., 2018; Nurafiah et al., 2018; Raniah et al., 2018). In other aspects, it is known that the learning motivation of students in Indonesia is still relatively low (Aunur Rohman, 2018; Hartini & Warmi, 2019; Sabrina et al., 2017). Seeing these varied kinds of research are a logical reason why developing these various competencies in mathematics learning in the contemporary era is essential.

The developed project learning model is integrated with ethnomathematics and technology. Ethnomathematics is a cultural study related to mathematics (Rosa & Orey, 2011). There have been many researches exploring the relationship between culture and mathematics. In Indonesia, there have been many cultural researches related to mathematics (Abdullah, 2017; Arisetyawan et al., 2014; Risdiyanti & Prahmana, 2018). Their research shows the relevance between mathematical concepts and cultural objects in several regions of Indonesia. Furthermore, the ethnomathematics integration with mathematics learning also provides positive results for the development of problem-solving skills (Mahendra, 2017; Ratuanik & Nay, 2017; Serin, 2019; Uyangör, 2012), mathematical creative thinking abilities (Katsap & Silverman, 2008; Ogunkunle et al., 2015), collaboration skills (Katsap & Silverman, 2008), and learning motivation (Katsap & Silverman, 2008; Mahendra, 2017).

Furthermore, the technology integration with this model development is based on the rationality that technology offers excellent opportunities to improve the quality of learning, expand students' active participation, and increase learning efficiency (Warner & Kaur, 2017). Previous researches have also shown that technology can be integrated with project-based

learning models to improve learning outcomes (Fang et al., 2021; Nurbekova et al., 2020; Untari et al., 2020). Technology is a component that continues to grow in a global society and has been used everywhere in an educational institution. Researches on the integrating technology effect in learning have provided positive evidence on problem-solving abilities (Kartini et al., 2021; Netwong, 2018; Roy et al., 2017; Zeeshan et al., 2021), creative thinking skills (Duncan, 2020; Granberg & Olsson, 2015; Pifarré, 2019; Švecová et al., 2014; Wheeler et al., 2002), collaboration skills (Duncan, 2020; Granberg & Olsson, 2015; Gündoğdu & Merç, 2021; Lawrence, 2002; Rizkiyah et al., 2020; Rustad & Andersen, 2022), and learning motivation (Alsawaier, 2018; Banfield & Wilkerson, 2014; Heafner, 2004; Tossavainen & Faarinen, 2019).

Rationale of the Study

Considering several prior research findings that culture is closely related to mathematics (Fauzi et al., 2022; Khanafiah, 2020; Khikmah & Sabrina, 2021; Khofifah et al., 2018; Risdiyanti & Prahmana, 2018; Sudirman & Lestari, 2017; Yanti & Haji, 2019). Therefore, many regional cultural objects contain mathematical concepts. However, there are still a few studies that report the results of ethnomathematics integration in learning mathematics. Ethnomatics has been extensively studied, but its actual implementation in the mathematics learning process has not been carried out. Teachers rarely include culture as a source of mathematical knowledge. On the other hand, the rapid development of technology and students' enthusiasm for computer technology is highly advanced (Warner & Kaur, 2017; Zakaria & Salleh, 2015). Meanwhile, this opportunity has not been widely used by teachers to improve the process of learning mathematics (The International Commision on Financing Global Education Opportunity, 2016). In the field of learning mathematics, it is also rare research and development (RnD) models that integrate project-based learning with ethnomathematics and technology. These several issues make an urgency to develop a project-based learning model that is integrated with ethnomathematics and technology.

The integrative learning model developed is project-based, integrated with ethnomathematics and technology in a series of learning activities. The main project that students must complete in implementing this model is to design Nusantara batik motifs in Geogebra using geometric transformation concepts. Four learning outcomes are measured in this research: 1) problem-solving skills, 2) creative thinking skills, 3) collaboration skills, and 4) learning motivation. Based on similar research reviews, there has not been any research that simultaneously examines the effect of an ethnomathematics and technology-integrated project-based learning model on these four variables. The difference in the type of project and the number of variables measured is what is novel in this research. This RnD results provide an adequate reference for practitioners in managing new mathematics classes to improve student learning achievement, especially problem-solving, creative thinking, collaboration, and learning motivation.

Purpose of the Study

Referring to the explanation above, the aim of this research is to find out, (1) the prototype of a project-based mathematics learning model that is integrated with ethnomathematics and technology in improving problem solving abilities, creative thinking, collaboration, and motivation to learn mathematics for high school students, and (2) the feasibility, practicality, and feasibility of the project in improving the ability of problem-solving, creative thinking, collaboration, and motivation to learn mathematics for high school students.

METHODS

Research Design

In this study, the authors using the Research and Development (RnD) design. The RnD approach refers to the model developed by Gall et al. (2007) with the stages presented in Table 1.

Table 1. Research Approach at Each Stage

No	Stages	Research Methods	Collecting Data Methods
1.	Research and information collecting	Descriptive	Questionnaires, interviews, observations, and documentation
2.	Planing	Review	Review
3.	Develop preliminary form of product	Evaluative	Validation sheet
4.	Preliminary field testing	Class action	Observation sheets and questionnaires
5.	Main product revision	Evaluative	-
6.	Main field testing	Class action	Tests, questionnaires, and observation sheets
7.	Operasional product revision	Evaluative	-
8.	Operasional field testing	Pseudo experimental	Tests, questionnaires, and observation sheets
9.	Final product revision	Evaluative	-
10.	Dissemination	-	-

Respondents

Products that have been pass suitable by experts are then used in field trials to assess the practicality and effectiveness of implementing the product. Initial product trials at the preliminary field-testing and main field-testing stages were carried out at the same school. Furthermore, product implementation at the operational field-testing stage was carried out at two different schools. Respondents involved in developing a project-based learning model integrated with ethnomathematics and technology included 6 validators, 4 math teachers, 145 students, and 10 observers.

The initial product trial on a small scale involved 12 students from good-category schools. Sampling was carried out by purposive sampling. Next, product trials on a larger scale were carried out in different schools but in the same category. The sampling technique used at this stage is cluster random sampling. Based on this technique, a class with a total of 27 students is obtained.

Furthermore, product implementation on a wide scale involved 106 students. Sampling was carried out using a stratified cluster random sampling technique, categorized into state schools and private schools. From each category, one school was then taken using a cluster random sampling technique. Next, using the same sampling technique, two classes were taken from each school. The first class was designated as the experimental, and the second class was defined as the control. Based on this sampling flow, the number of samples in the experimental class was 54 students, while the control class was 52 students. The research sample characteristics for the implemented product are presented in Table 2.

Tabel 2. Number of Research Samples

No	Group	School	Total
1.	Experiment	Class XI Science 1 National School	32
		Class XI Science 1 Private School	22
2.	Control	Class XI Science 5 National School	32
		Class XI Science 2 Private School	20

Table 3. Research Instruments

No	Component	Instrument	Assess Data	Respondents
1	Needs analysis	a. Interview guidelines b. Questionnaire of need assessment	a. Learning process b. Problem analysis c. Learning media d. Responses to the implementation of learning models	a. A headmaster b. Math teachers c. Students
2	Assessment instrument	Validation sheet	a. Problem-solving skill b. Creative thinking ability c. Collaboration ability d. Motivation to learn mathematics	a. Experts b. Mathematics Teachers
3	Product eligibility	Validation sheet	a. Learning model book b. Learning media	Experts
4	Product practicality	a. Practicality questionnaire b. Observation sheet	a. Learning model book b. Learning Media c. Learning experience	a. Observers b. Math teachers c. Students
5	Product Effectiveness	a. Written test b. Observation sheet c. Likert scale	a. Problem solving skill b. Creative thinking ability c. Collaboration capabilities d. Motivation to learn mathematics	Students

Instruments

The instruments in this RnD are presented in Table 3. The instrument used to measure problem-solving and creative thinking skills is a written test with 5 questions in the form of essays. The collaboration skills instrument is in the form of an observation sheet, and the motivational instrument for learning mathematics is in the form of a Likert scale. The validity of the four instruments is verified using the Aiken validity index. Therefore, the four instruments were further proven for construct validity using the Confirmatory Factor Analysis (CFA) technique. Furthermore, the instrument's reliability for problem-solving ability, creative thinking ability, and learning motivation questionnaire was estimated using the Cronbach alpha formula, and the instrument for collaboration ability was estimated for reliability using the Intraclass Correlation Coefficient formula.

Data Analysis

The model validity analysis is based on studies conducted by experts on the various components of the model and the supporting tools developed. Aspects of the validated model components include 1) theoretical basis, 2) syntax, 3) social system, 4) reaction principles, 5) support systems, and 6) instructional and accompaniment impacts (Joyce & Weil, 2003). The validity level of the model and its supporting devices were analyzed using the Aiken validity index. Meanwhile, to estimate the reliability of the learning model and its supporting devices, the Intraclass Correlation Coefficient (ICC) is used. The model's practicality is seen based on the analysis of the observation results of the implementation of learning and the student's responses after participating in the learning series. The product practicality criteria used in this research refer to the ideal rating system. Furthermore, the effectiveness model integrated with ethnomathematics and technology is analyzed at the main field and operational field-testing stages. The data analysis technique used at this stage was parametric test statistics in the form of paired-sample t-test and one-way multivariate analysis (Manova) of Hotelling's Trace methods. Meanwhile, the normalized-gain formula is used to see the level of product effectiveness.

RESULTS AND DISCUSSION

Results

Learning Model Description

The project-based learning model integrated with ethnomathematics and technology in this research was developed based on the philosophy of constructivism. This learning model is designed in five main components, namely: syntax, reaction principle, social system, support system, as well as instructional impact and accompaniment. Furthermore, the construction of the various components can be seen in Figure 1.

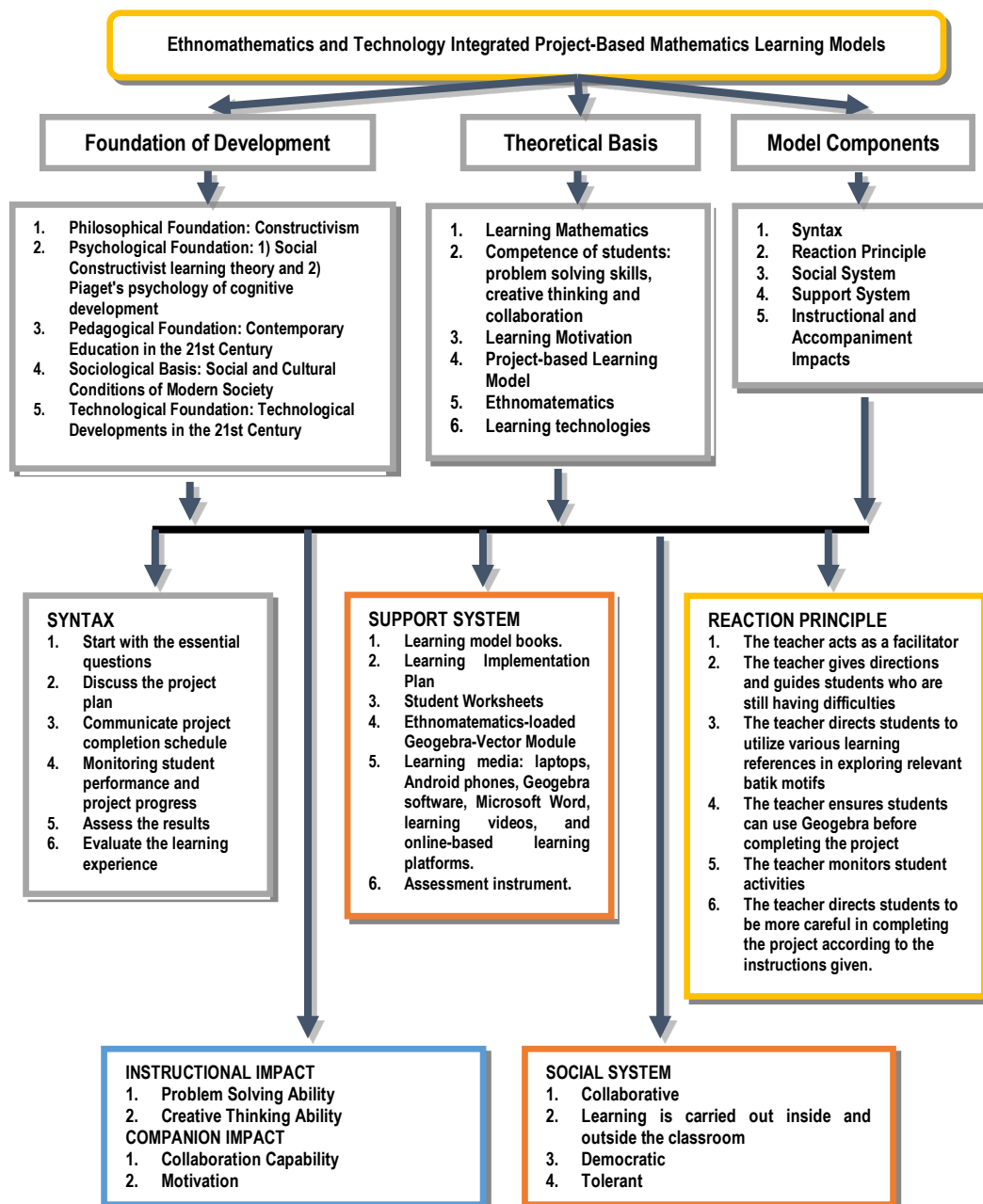


Figure 1. Learning Model Construction

Model Feasibility

The validity and reliability of the ethnomathematics and technology integrated project-based learning model and its supporting tools are presented in Table 4.

Table 4. Validity and Reliability Analysis Results

No	Product	Aiken Validity Index	Alpha Coefficient	Criteria
1	Learning Model	.88	.76	Valid and reliable
2.	Learning implementation plan	.83	.74	Valid and reliable
3.	Student worksheet	.82	.74	Valid and reliable
4.	Learning module	.80	.73	Valid and reliable
5	Problem solving ability test	.92	.84	Valid and reliable
6	Creative thinking ability test	.92	.91	Valid and reliable
7	Observation sheets for collaboration skills	.93	.89	Valid and reliable
8	Likert scale for motivation	.92	.90	Valid and reliable

Table 5. The Result of Construct Validity Proving

Variables	Indicators	SLF	T-Value	Error	CR	VE
Problem Solving	Problem Understanding	.64	5.70	.54	.83	.55
	Plan making	.75	9.97	.44		
	Plan implementation	.77	5.43	.41		
	Rechecking	.79	5.76	.38		
Creative Thinking	Fluency	.94	4.12	.12	.95	.88
	Flexibility	.95	4.32	.10		
	Originality	.94	5.30	.12		
Collaborate Ability	Contribution	.54	***	.71	.89	.60
	Time management	.58	5.93	.67		
	Problem-solving	.58	5.98	.66		
	Cooperation	.94	7.76	.12		
	Research methodologies	.94	7.78	.11		
	Synthesis	.94	7.77	.12		
Motivation	Intrinsic goal orientation	.55	***	.70	.85	.51
	Extrinsic goal orientation	.56	5.89	.69		
	Assignment score	.59	6.14	.65		
	Confidence in learning	.58	6.06	.66		
	Self-efficacy	.93	8.00	.13		
	Anxiety level	.93	8.02	.11		

Table 6. Practicality Test Results

Development Stages	Respondents	Percentage (%)	Category
Preliminary Field Testing	Teachers	90	Very Practical
	Students	72	Practical
	Observers	92	Very Practical
Main Field Testing	Teachers	91	Very Practical
	Students	73	Practical
	Observers	88	Very Practical

Based on the validity test, as shown in Table 4, it is known that the project-based mathematics learning model integrated with ethnomathematics and technology and its supporting devices has an Aiken validity index above .80. These results indicate that product validity is in the high category. Meanwhile, based on reliability estimation using the Alpha formula, it is known that the model and its supporting devices have a reliability coefficient above .70. These results indicate that all the products developed in this study have met the reliable criteria.

The construct validity tests with CFA on the four assessment instruments are presented in Table 5. Based on Table 5, it is known that all indicators for each variable have a Standardized Loading Factor (SLF) value of more than .40, and the calculated t-value for all indicators is more than 1.96. Therefore, the indicators that form each variable are valid. Furthermore, for each instrument, a Construct Reliability (CR) value of more than .70 and a

Variance Extranced (VE) value of more than .50 were obtained. Therefore, these four instruments have excellent construct reliability.

Table 7. Data at the operational field-testing stage

Statistic	Problem Solving	Creative Thinking	Collaboration	Motivation
<i>Experimental Class</i>				
Means	75.37	66.59	79.57	117.70
Median	75.00	65.00	80.00	117.50
Variance	80.99	102.21	70.78	99.61
Standard Deviation	9.00	10.11	8.41	9.98
Minimum Value	50.00	42.00	60.00	99.00
Maximum Value	90.00	83.00	96.00	136.00
Range	40.00	41.00	36.00	37.00
<i>Control Class</i>				
Means	64.23	54.50	64.54	104.17
Median	65.00	55.00	65.00	102.50
Variance	91.55	122.69	94.14	74.34
Standard Deviation	9.57	11.08	9.70	8.62
Minimum Value	45.00	37.00	44.00	87.00
Maximum Value	85.00	82.00	85.00	124.00
Range	40.00	45.00	41.00	37.00

Learning Models Practicality

The practicality of the project-based learning model integrated with ethnomathematics and technology in this research was determined based on teacher and student responses and the results of assessments carried out by observers. The model's practicality test is presented in Table 6.

Table 6 shows that according to teacher perceptions and observer assessments, this learning model is very practical. This learning model is included in the practical category based on student perceptions. Referring to these results generally, the project-based learning model is integrated with ethnomathematics and technology, fulfilling the practical criteria in its use.

Learning Models Effectiveness

Product effectiveness at the main field-testing stage was analyzed using one-way MANOVA. This test statistic is used after fulfilling several analysis requirements: multivariate normality test, homogeneity of variance and covariance matrices, and multicollinearity test.

Data Description

The results of the final test in the experimental class obtained a mean for problem-solving (75.37), mathematical creative thinking (66.59), collaboration ability (79.57), and learning motivation (117.70). Among the four variables studied, the highest range is found in the ability to think creatively (41), while the lowest is found in collaboration (36). Data on the operational field-testing stage is presented in Table 7.

The Multivariate Normality Test

The multivariate normality test was carried out by constructing a scatter plot and testing the correlation between the Mahalanobis distance value and chi-squared. Scatter plot visualization for the experimental class is presented in Figure 2, The scatter plot for the control class is presented in Figure 3.

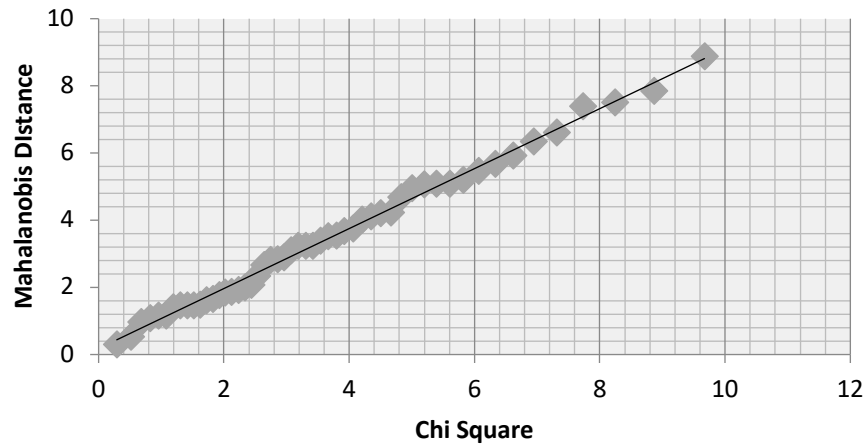


Figure 2. Scatter Plot for Experiment Class

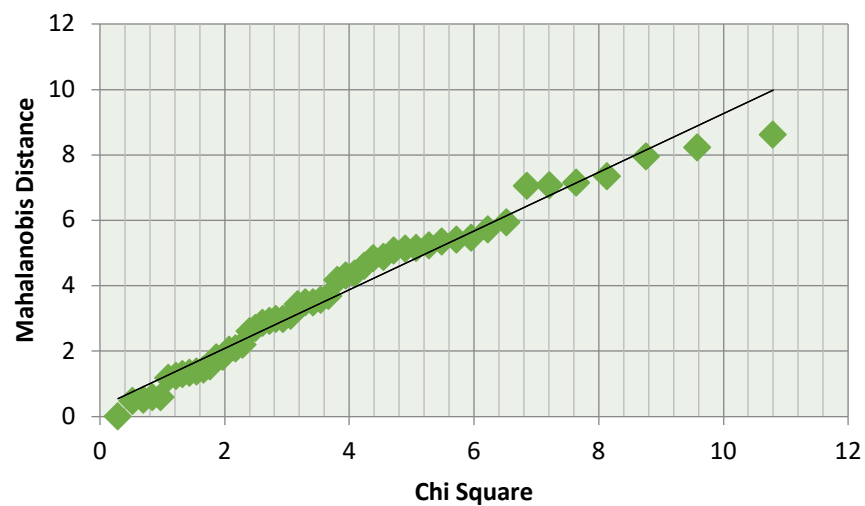


Figure 3. Scatter Plot for Control Class

Based on the scatter plot visualization, it is known that the distribution of the post-test data in the experimental and control class tends to form a straight line. For the correlation between the value of the Mahalanobis distance and chi-square in experimental group, a correlation coefficient of .967 is obtained with an observational significance level of .000. For the correlation between the Mahalanobis distance value and chi-squared in control group, a correlation coefficient of .981 was obtained with an observational significance level of .000, indicating a significant correlation between the two values. Based on the visualization of the scatter plot and the correlation test results, it is known that the data in the experimental and control group is normally multivariate distributed.

Homogeneity Test of the Variance and Covariance

Furthermore, to find the homogeneity of the variance and covariance matrices using the Box's M test. Based on the test results, an observed significance value of .849 was obtained. Because it has an observational significance of more than .05, all populations' variance and covariance matrices are the same or homogeneous.

Table 8. Multicollinearity Test Results

Dependent Variables	Collinearity Statistics	
	Tolerance	VIF
Problem Solving	.27	3.71
Creative Thinking	.32	3.17
Collaboration	.30	3.31
Motivation	.40	2.49

Table 9. Multivariate Test Results

Effect	F	Hypothesis df	Error df	Sig.
Intercept	4000.07	4.00	101.00	.00
Model	20.57	4.00	101.00	.00

Table 10. Univariate Test Results

Dependent Variables		Sum of Squares	df	Mean Square	F	Sig.	Marginal Means	
							Experiment	Control
Problem Solving	Contrast	3287.23	1	3287.23	38.15	.00	75.37	64.23
	Error	8961.82	104	86.17				
Creative Thinking	Contrast	3873.74	1	3873.74	34.51	.00	66.59	54.50
	Error	11674.04	104	112.25				
Collaboration	Contrast	5988.71	1	5988.71	72.83	.00	79.57	64.54
	Error	8552.13	104	82.23				
Motivation	Contrast	4849.84	1	4849.84	55.61	.00	117.70	104.17
	Error	9070.71	104	87.22				

Multicollinearity Test

The multicollinearity test results were analyzed using the Variance Inflation Factor (VIF) and Tolerance values. The results of the multicollinearity test are presented in the Table 8. Based on Table 8, it is known that the tolerance value for all variables is more than .01. Meanwhile, the VIF value for all variables is less than 10. These results indicate that there is no multicollinearity problem in this study.

Multivariate and Univariate Test

Based on the analysis of product trial results at the operational field-testing stage using the one-way MANOVA, an F-count value of 20.57 was obtained with a significance of .00 for the multivariate. Next, a multivariate test using the Hotelling Trace test statistics is presented in Table 9. As for the results of the univariate test, it can be seen in the Table 10.

Based on Table 10 it can be concluded that there was a difference between the ethnomathematics and technology-integrated project-based learning model and the direct learning model simultaneously and on each dependent variable because the practical significance was less than .05. Referring to the marginal average comparison results, it can be seen that the project-based mathematics learning model integrated with ethnomathematics and technology is better than the direct learning model. These results occurred in increasing solving ability, creative thinking ability, collaboration ability, and motivation to learn mathematics simultaneously and in each dependent variable studied.

N-Gain Test Results

Further analysis with N-Gain shows that the project-based mathematics learning model integrated with ethnomathematics and technology has a higher level of effectiveness than the direct learning model. Table 11 shows the results of the N-Gain test for experimental and control classes.

Table 11. N-Gain Value

Group	Variable	Average Value		N-Gain	Category
		Pretest	Posttest		
Experiment	Problem-Solving	53.61	75.37	.47	Medium
	Creative Thinking	50.06	66.59	.33	Medium
	Collaboration	62.97	79.57	.45	Medium
	Motivation	99.00	117.70	.37	Medium
Control	Problem-Solving	54.90	64.23	.20	Low
	Creative Thinking	51.60	54.50	.06	Low
	Collaboration	62.54	64.54	.05	Low
	Motivation	98.54	104.17	.11	Low

Furthermore, based on the analysis of the effective contribution it is known that the contribution of the project-based mathematics learning model integrated with ethnomathematics and technology to the four dependent variables simultaneously is 45%. The contribution of the model to problem solving ability is 27%, to thinking creatively is 25%, to collaboration ability is 41%, and to motivation to learn mathematics is 35%. These results indicate that the project-based mathematics learning model integrated with ethnomathematics and technology positively contributes to increasing solving abilities, creative thinking skills, collaboration skills and motivation to learn mathematics. Among the improvements in the four variables, it is known that this learning model makes the most significant contribution to collaboration skills. The smallest variable contribution is the ability to creative mathematical thinking.

Discussion

Model Characteristics

The philosophical foundation for the development of an integrated project-based learning model of ethnomatematics and technology is the constructivism philosophy. The psychological foundation is the psychology of social constructivism learning theory and the psychology of Piaget's cognitive development. Furthermore, the pedagogical foundation refers to the contemporary education system in the 21st century. Moreover, the sociological foundation refers to the social and cultural conditions of modern society and technological foundations based on technological developments in the 21st century. Syntax refers to project-based learning in general, namely: 1) starting with essential questions, 2) designing a project plan, 3) making a schedule, 4) monitoring students and project progress, 5) assessing results, and 6) learning experiences evaluation.

Furthermore, the social systems developed in this model implementation are 1) collaborative project completion; 2) learning activities inside and outside the classroom; and 3) the learning process democratically and entirely tolerant. The reaction principles in this implementation learning model are 1) the teacher acts as a facilitator, mediator, and motivator; 2) the teacher gives instructions and guides students who are still having difficulty in completing the tasks given; 3) the teacher monitors the students' performance during the project completion process; 4) the teacher encourages students to be actively involved and creative in learning; and 5) students help each other if anyone still has difficulty in completing the tasks given. Meanwhile, the supporting system of this learning model includes 1) learning model guides; 2) learning implementation plans; 3) student worksheets; 4) learning modules; 5) assessment instruments; and 6) learning media which include: laptops, smartphones, geogebra software, desktop applications, learning videos, and online learning platforms.

These integrative learning model components have been designed in full according to the opinion of (Joyce & Weil, 2003) in the form of syntax, the principle of reaction, social system, supporting systems, and instructional impacts of the accompaniment. The project-based

learning model characteristics in this study have been formulated based on established theories as described in (Bell, 2010; Pearlman & Thomas, 2000; Pendidikan, 2019). The Integration Scheme of Project -Based Learning Model with Ethnomatematics and Technology has been referred to several previous studies that have provided satisfactory results on learning achievements, such as research conducted by (Mahendra, 2017; Muwahiddah et al., 2018; Ratuanik & Nay, 2017; Verner et al., 2013).

The Model's Influence on Problem-Solving Abilities

The F-count value of the product trial in the final stage using the one-way Manova test is 20.57 with a significance level of .000. These results indicate that simultaneously there are differences in the influence between the project-based learning model integrated ethnomatematics and technology with the direct learning model of the four dependent variables. Furthermore, based on the univariate test, the F-count value was obtained for the problem-solving capability variable of 38.15 with an observation significance level of .000. Referring to the results of the marginal average comparison, the developed mathematic learning model is better than the direct learning model in improving the ability to solve. Further analysis with N-Gain shows that the developed mathematical learning model has a higher level of effectiveness in problem-solving capabilities compared to direct learning models. Meanwhile, the model effectiveness in the problem-solving aspect is 27%, so it is classified as a positive impact.

Problem-solving abilities are developed in this model by analyzing relevant batik motifs, placing the object study in the technology used, solving problems at the project completion, and evaluating learning outcomes. Students have been trained to use various concepts, principles, and strategies in solving mathematical problems at the learning outcome assessment. The students are also faced with various non-routine problems to help them develop their mathematical problem-solving skills. These various activities have contributed to improving students' ability to solve problems. This result is in line with the finding of NCTM (2000) which states that the ability of students to solve the same problem using mathematical perspectives variety will improve their ability in mathematics.

Furthermore, implementing an ethnomatematics and technology-integrated project-based learning model also focuses on student activities based on team performance. At this stage, students share ideas and experiences to increase further students' ability to think mathematically. This team-based learning scheme is an advantage because it improves students' data recall, thinking skills, and problem-solving (Choirul, 2020).

These research findings are in line with several previous researches which show that the project-based learning model contributes significantly to improving mathematical problem-solving skills (Chiang & Lee, 2016; Hidayati & Wagiran, 2020; Jaenudin et al., 2020; Jalinus, 2017; Kartini et al., 2021; Koutrouba & Karageorgou, 2013). The ethnomatematics integration to project-based learning is also known to contribute positively to improving mathematical problem-solving skills (Chiang & Lee, 2016; Mahendra, 2017; Muwahiddah et al., 2018; Perdana & Isrokatun, 2019; Ratuanik & Nay, 2017; Serin, 2019; Uyangör, 2012). Furthermore, using mathematics learning technology improves students' problem-solving abilities (Kartini et al., 2021; Netwong, 2018; Roy et al., 2017; Zeeshan et al., 2021). The similarity of these research findings with several previous studies has provided a more complex picture regarding the contribution of project-based mathematics learning models integrated with ethnomatematics and technology in improving mathematical problem-solving abilities.

The Model's Influence on The Ability to Think Creatively

Univariate tests for variable creative thinking skills obtained an F-count value of 34.51 with a significance level of .05. Referring to the results of the marginal average comparison, the developed mathematics learning model is better than the direct learning in improving the

ability to think creatively. Further analysis with N-Gain shows that the mathematical learning model developed has a higher level of effectiveness in improving creative thinking skills compared to direct learning models. Meanwhile, based on the analysis of the effective contribution, it is known that the developed mathematic learning model on the ability to think creatively is 25%. Therefore, it is classified as having a positive impact on improving the ability to think creatively.

Creativity in implementing this model occurs when students are given the freedom to determine the cultural object being studied, construct it using technology and then solve open problems through various problem-solving strategies. This rationality is built on a theory that the scope of creativity includes problem-solving, investigation, making patterns, thinking, and strategy (Whitcombe, 2014). On the other hand, the ability to think creatively is developed in this model through a team performance-based investigative process. Through collaborative work, students' knowledge and insights become broader and more profound because students share ideas, knowledge, and experiences so that an increase in the quality of work appears, both cognitively and affectively. This process has contributed to helping students develop their creative thinking skills. The findings of this study are also in line with previous studies, which show that the project-based learning model is effective in increasing creative thinking skills (Bell, 2010; Hanif et al., 2019; Jaenudin et al., 2020; Koutrouba & Karageorgou, 2013; Xu & Liu, 2010). The ethnomathematics integration in learning also has a significant effect on increasing students' creative thinking abilities (Katsap & Silverman, 2008; Ogunkunle et al., 2015). The use of technology in learning is also known to be able to improve students' creative thinking skills (Duncan, 2020; Granberg & Olsson, 2015; Pifarré, 2019; Švecová et al., 2014; Wheeler et al., 2002). This research finding relevance to previous research provides an adequate reference for mathematics teachers in managing classes to improve their mathematical creative thinking skills. Even though the model's effective contribution to this ability is the lowest compared to the other variables, this model significantly influences the ability to think mathematics creatively.

The Model's Influence on The Collaboration Ability

Based on the univariate test for the collaboration ability variable, it obtained an F-value of 72.83 with an observation significance level of .000. Therefore, there is a difference between the developed mathematic learning model and the direct learning model in improving collaboration skills because the significance value is less than .05. Referring to the marginal average comparative value, the developed mathematics learning model is better than the direct learning model in increasing collaboration skills. Further analysis with N-gain shows that the developed mathematics learning model also has a higher effectiveness level in improving collaboration abilities. Meanwhile, the effectiveness level of the developed mathematics learning model on collaboration skills was 41%. Therefore, this learning model innovation has a positive impact on increasing collaboration capabilities. In addition, this integrative learning model has the most significant impact on collaboration abilities based on the four variables measured.

In implementing the project-based learning model, students construct knowledge by involving their mates in a team-based learning format. In completing projects and making schedules collaboratively between students with their teachers and mates. While completing the project, students are tasked with exploring, identifying, and learning mathematics through a group work system. Collaboratively, they are given the flexibility to develop projects based on the exploration results and then present them in class. The collaboration process is also done in and outside the classroom using various relevant communication media. These various activities are designed to make students maximally share activities to improve their performance in learning. This learning method is relevant to the finding of P21 (2015) that for

developing collaboration skills, students need to listen effectively related to the reasoning of their peers. Students also need to be given sufficient time allocation to be actively involved in group work to describe solutions to solving the mathematical problems they are facing (P21, 2015).

In another aspect, project completion in implementing a project-based learning model integrated with ethnomathematics and technology requires significant resources. This is because the given project requires students' high-level thinking skills and the availability of adequate learning technology. However, students' collaborative work can complete a given project effectively and efficiently. Even though some groups did not complete the project optimally, it was generally known that most groups could complete it according to the game's mutually agreed rules. Therefore, students are more motivated to work collaboratively. This condition is in line with the findings of (Choirul, 2020), which states that a job will be easier to complete if it is done collaboratively rather than individually. Meanwhile, the technology application in the learning applications form, functioning as learning tools and communication media, has also been used by students to complete projects collaboratively. With adequate environmental and device support, collaboration processes will run more effectively (Choirul, 2020). These various activities have helped students develop their collaboration skills.

These research findings are in line with previous studies that the project-based learning model improves students' collaboration skills (Bell, 2010; Koutrouba & Karageorgou, 2013; Maija & Haatainen, 2019; Verner et al., 2013; Xu & Liu, 2010). Previous research also revealed that mathematics integration with ethnomathematics positively affects students' collaboration skills (Katsap & Silverman, 2008). The use of computer-based technology in learning also supports the development of students' collaboration skills (Duncan, 2020; Granberg & Olsson, 2015; Gündoğdu & Merç, 2021; Lawrence, 2002; Rizkiyah et al., 2020; Rustad & Andersen, 2022).

The Models' Influence on Learning Motivation

The univariate test results for the learning motivation variable obtained an F-value of 55.61 with an observation significance level of .05. Referring to the marginal average comparison results, this mathematics learning model is better than the direct learning model in increasing students' learning motivation. Further analysis with N-gain shows that the developed mathematics learning model has a higher level of effectiveness in increasing learning motivation compared to the direct learning model. The effectiveness score of the developed mathematics learning model is 35% on learning motivation. Therefore, a project-based mathematics learning model integrated with ethnomathematics and technology is able to have a positive impact on increasing learning motivation.

Ethnomathematics and technology-integrated project-based mathematics learning models involve higher-order thinking processes. One of the characteristics of projects that students have to work on is not easy to complete because they need to use high reasoning abilities, in-depth mathematical knowledge, and various strategies to complete the project. Referring to the findings of (Schunk, 2012), this series of processes can increase students' learning motivation.

Furthermore, in another learning phase, implementing a project-based learning model integrated with ethnomathematics and technology is designed by linking objects in everyday life with the mathematical concepts being studied. This process has raised the awareness that mathematics is closely related to students' daily lives. Connecting the material being studied and everyday life can strengthen students' motivation to learn the material. This is in line with the opinion of Santrock (2007), which states that making connections between learning activities and various factors under students' control can increase learning motivation internally.

On the other hand, the social system in implementing a project-based learning model integrated with ethnomathematics and technology is directed at mutual assistance between

students through a group work system. The collaborative work system has made projects that must be completed easier, so students are more motivated to master the subject matter (Choirul, 2020). In addition, learning with this model also emphasizes the values of democracy and tolerance. Teachers have positioned themselves as facilitators, mediators, and motivators. Feedback and social support increase students' motivation to learn (Brophy, 2004; Schunk, 2012).

Various activities in project-based learning are integrated with ethnomathematics and technology to accommodate the development of student's motivation to learn mathematics. These research findings have supported several previous empirical studies which showed that the project-based learning model increased students' learning motivation (Bell, 2010; Chiang & Lee, 2016; Holmes & Hwang, 2016; Kaldi et al., 2011; Koutrouba & Karageorgou, 2013; Mahendra, 2017; Maija & Haatainen, 2019; Terrón-López et al., 2017). Ethnomathematics integration with mathematics learning also has a positive effect on increasing students' learning motivation (Katsap & Silverman, 2008; Mahendra, 2017). The use of technology in learning also increases students' learning motivation (Alsawaier, 2018; Banfield & Wilkerson, 2014; Heafner, 2004; Tossavainen & Faarinen, 2019). The results of this study and several previous studies are helpful for teachers to develop their students' learning motivation.

Implications

The project that students have to complete collaboratively is to construct batik motifs in Geogebra using the concept of transformational geometry. Differences in the types of projects and the number of variables measured are the novelties offered in this study. For the education process in a country, this model contributes to developing the competencies needed in the 21st century and maintaining the nation's identity through its culture. As a final achievement, a project-based mathematics learning model integrated with ethnomathematics and technology improves the process and output of mathematics learning. Based on the results of case studies in Indonesia, using this method to construct batik motifs has been proven to maintain the country's culture and the quality of mathematics learning. Therefore, this learning method is prospective to be applied in every country with a different culture.

Limitations and Suggestions for Further Research

This RnD has been pursued as much as possible by the objectives and procedures set. However, this study has some limitations: ethnomathematics studies integrated with this research are limited to batik motifs. Many other cultural studies are still relevant to mathematical concepts, such as traditional houses, regional arts, cultural values, and so on. Another limitation is that the competencies measured are limited to four variables: 1) problem-solving abilities, 2) mathematical creative thinking skills, 3) collaboration skills, and 4) motivation to learn mathematics. Many other competencies need to be developed in the mathematics study process.

Before implementing an ethnomathematics and technology-integrated project-based learning model, the teacher must have mastered the use of the Geogebra application and ensure the availability of adequate internet access. Exploration of cultural studies via the internet requires a strong internet connection. In addition, educators are also advised to apply learning techniques that can activate students' performance in the class discussion process, such as direct questioning, student self-explanation, and elaborative interrogation. Furthermore, it is recommended for further research to take different materials, cultural studies, and technology so that a more comprehensive picture will be obtained regarding the effectiveness of the project-based learning model integrated with ethnomathematics and technology in mathematics learning.

CONCLUSION

Based on the analysis of product implementation at the operational field-testing stage using one-way MANOVA tests, it was concluded that there is a difference simultaneously in the influence between the project-based learning model integrated with ethnomathematics and technology compared to the direct learning model. The abilities tested are problem-solving, creative thinking, collaboration, and motivation to learn collectively. Based on the results of univariate tests, it is known that this integrative model is able to provide better effects for each variable compared to the direct learning model. The further analysis results with n-gain show that the increase in each dependent variable in the class using the project-based learning model is higher than in the direct learning model. This shows that the project-based mathematics learning model effectively improves problem-solving skills, creative thinking, collaboration, and motivation simultaneously and partially. Based on the contribution of the model, it is known that the project-based mathematics learning model has a positive impact on increasing solving abilities, creative thinking skills, collaboration skills, and motivation to learn mathematics. The project-based mathematics learning model has the highest impact on collaboration skills among the four dependent variables increases. In contrast, the variable with the lowest impact is the ability to think creatively.

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AUTHOR CONTRIBUTION STATEMENT

WW, HR and WS contributed to designing the study. WW conducted research in schools, analyzed the data and wrote the paper. HR and WS validated all the product and instruments developed. All authors had approved the final version.

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