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## The Effect of *Problem-Based Learning* on Mathematical Connection Ability in the Context of Learning Style at UPT SMAN 6 Jeneponto

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### Abstract

This study was motivated by the low mathematical connection ability of students at UPT SMAN 6 Jeneponto, which was caused by the dominance of teacher-centred learning and the lack of student involvement in the learning process. The focus of this research is to examine the effect of group and paired *problem-based learning* models on students' mathematical connection skills, by considering learning styles (visual, auditory, kinesthetic). The purpose of the study was to determine the effect of the PBL model on mathematical connection ability based on learning style. This research uses quantitative research with a *quasi-experimental* design and data analysis using ANCOVA. The results showed that the group PBL model was more effective in improving mathematical connection skills than paired PBL, with the highest improvement in kinesthetic learners. However, learning style did not have a significant effect on mathematical connection skills. This study concludes that the group PBL model can be an effective alternative in improving students' mathematical connection skills, regardless of their learning style.

**Keywords:** *Problem-Based Learning*, Mathematical Connection, Learning Style.

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### INTRODUCTION

Mathematics is a science that is very close to everyday life and underlies the development of science and technology. Mathematics is an insight that has a strong correlation with the development and progress of the nation (Ornawati, Hendrastuti & Franita, 2022). According to Gokalp (2020), mathematics is also a study of patterns and relationships between abstract concepts that are interrelated with each other.

Mathematics, as a subject that has an important role in education, not only serves as a tool for solving problems but also as a basis for understanding various concepts in other sciences. The subject of mathematics consists of various topics that are interconnected with other topics. The relationship is not only between topics in mathematics but also interrelated with other disciplines and with everyday life (Laili & Puspasari, 2019).

*The National Council of Teachers of Mathematics* (NCTM) sets standards for mathematical abilities, such as problem solving, reasoning, communication, connection, and representation that must be possessed by students (Aisyah & Usdiyana, 2022). Of all the mathematical abilities, connection ability is still very low in UPT SMAN 6 Jeneponto, based on the facts in the field. Initial observations at UPT SMAN 6 Jeneponto showed the dominance of teacher-centred learning, where students tend to be passive and not actively

involved in the teaching and learning process. Teachers focus more on delivering mathematical concepts and formulas, without linking them to the context of everyday life. As a result, learners struggle to relate mathematical concepts to the real world and other disciplines, which hinders the development of their mathematical connection skills. According to Siagian (2016), mathematical connection is one of the basic abilities that students in secondary school must master. Learners are expected to be able to relate mathematics learning in the form of facts, concepts, principles, operations, and mathematical relationships in a field of study, across fields of study, across fields of science, and with life.

Seeing these conditions, a more effective learning approach is needed to improve students' mathematical connection skills. One solution that can be applied is the *problem-based learning* (PBL) learning model. *Problem-based learning* is a learning model that provides solutions in the learning process that can foster knowledge and structured ways of thinking through stages in solving problems (Ernia & Mahmudah, 2023). Fatharani, Irvan, and Aziz (2024) showed that *problem-based learning* has a positive influence on students' mathematical connection skills. This learning model also helps students develop mathematical connection skills.

In addition to the use of learning models, one of the other aspects that can influence mathematical connection skills is learning style. The appropriate learning style is the key to one's success in the learning process. Gunawan (Khaeroh, Anriani & Mutaqin, 2020) states that learning style is the preferred way of thinking, processing, and understanding information. Furthermore, DePorter & Hernacki (Ornawati, Hendrastuti & Franita, 2022) revealed that learning style is a combination of how students absorb, then manage and process information. If educators are able to observe the learning style tendencies of students, then it can be useful for developing students' competencies from the content/material taught by educators. Learning styles (visual, auditory, kinesthetic) affect the way they process mathematical information. Effective learning should consider students' dominant sensory modality to optimise cognitive skill development (Sheromova et al., 2020).

Although many studies have examined the effect of learning models on mathematical connection skills, there is still a lack of research that specifically explores the effect of learning styles on *problem-based learning* models. Most previous studies tend to focus on one aspect only, either the learning model or learning style, without linking the two in depth. Previous research often does not consider specific local contexts, such as at UPT SMAN 6 Jeneponto, which has diverse learner characteristics, including different social, economic, and cultural backgrounds. This may affect the way learners learn and interact in the learning process. Therefore, this study aims to explore the group *problem-based learning* and paired *problem-based learning* models on learners' mathematical connection skills, as well as how learners' learning styles can affect learning outcomes to fill the gap by observing the effect of *problem-based learning* on learners' mathematical connection skills, taking into account different learning styles among learners.

## METHODS

This study used a *quasi-experimental* approach with a 2x3 factorial design. The form of the research design is shown in Table 1.

Table 1. Research design

Learning Model	Mathematical connection ability with learning style		
	Visual (V)	Auditory (A)	Kinesthetic (K)
PBL in groups	$\mu_{11}$	$\mu_{21}$	$\mu_{31}$
PBL in pairs	$\mu_{12}$	$\mu_{22}$	$\mu_{32}$

The population was all students of class X UPT SMAN 6 Jeneponto, which amounted to 270 people. Then the samples selected by the *purposive sampling* technique were class X.IKM 1 with *problem-based learning in groups* and class X.IKM 4 with *problem-based learning in pairs*. Data analysis includes a normality test, a homogeneity test, a covariate linearity test, a regression coefficient homogeneity test, and a covariate analysis test (ANCOVA).

## RESULTS & DISCUSSION

### Results

#### 1. Description of Learning Style Results

The results of the learning style categorisation research were carried out, referring to the learning style questionnaire data filled in by students. Then the results of filling out the questionnaire are processed and classified into learning style modalities, namely visual, auditory, and kinesthetic. The data on the learning styles of students in classes X.IKM 1 and X.IKM 4 are presented in Table 2.

Table 2. Data on students' learning styles

<i>Problem-Based Learning</i>	Learning Style			Total
	Visual	Auditory	Kinesthetic	
X.IKM 1	10	6	16	32
X.IKM 4	10	4	14	28
Total	20	10	30	60

Based on Table 2, data on the learning styles of students in classes X.IKM 1 and X.IKM 4 show a diverse distribution. In class X.IKM 1, there are 10 learners with visual learning style tendencies, six learners with auditory learning style tendencies, and 16 learners with kinesthetic learning styles, with a total of 32 learners. Meanwhile, in class X.IKM 4, there are 10 learners with visual learning style tendency, four learners with auditory learning style, and 14 learners with kinesthetic learning style tendency, with a total of 28 learners.

## 2. Mathematical Connection Ability based on Learning Style

## (a) Problem-based learning in groups in class X.IKM

Table 3. Descriptive Statistics of Mathematical Connection Ability Results

DATA	PRETEST			POSTTEST		
	V	A	K	V	A	K
N	10	6	16	10	6	16
Mean	24,4	26,0	25,2	69,7	69,4	73,7
Sd	12,1	11,0	11,6	10,4	4,9	10,0
Min	12,0	12,0	12,0	63,3	63,3	60,0
Max	48,0	40,0	44,0	96,7	73,3	90,0

In Table 3, the visual learning style of applying (PBL) in groups improves students' mathematical connection skills. The pretest average was 24.4, and the posttest increased to 69.7. In the auditory learning style, the average pretest result was 26.0, while the posttest showed an increase to 69.4. In the kinesthetic learning style, the pretest reached 25.2, and the posttest increased significantly to 73.7. Distribution data for all learning styles showed a change after the application of PBL in groups, also showing fluctuations in the results of students' mathematical connection skills.

(b) Problem-based *learning* in pairs in class X.IKM 4.

Table 4. Descriptive Statistics of Mathematical Connection Ability Results

DATA	PRETEST			POSTTEST		
	V	A	K	V	A	K
N	10	4	14	10	4	14
Mean	26,8	18,0	18,5	65,3	64,2	65,0
Sd	12,8	9,5	7,1	7,2	5,0	7,1
Min	12,0	12,0	12,0	56,7	60,0	60,0
Max	48,0	32,0	32,0	76,7	70,0	80,0

In the visual learning style, there is an increase in students' mathematical connection skills after using the problem-based learning (PBL) learning model in pairs. The pretest average was 26.8 with a standard deviation of 12.8, and after the application of PBL, the posttest average reached 65.3 with a standard deviation of 7.2. The minimum pretest score was 12.0 and the maximum was 48.0, while the posttest had a minimum score of 56.7 and a maximum of 76.7. For the auditory learning style, the pretest average was 18.0 with a standard deviation of 9.5, increasing to 64.2 on the posttest with a standard deviation of 5.0. In the kinesthetic learning style, the pretest average was 18.5 with a standard deviation of 7.1, and after PBL, the posttest average was 65.0 with a standard deviation of 7.1. The overall results showed that paired PBL was effective in improving mathematical connection skills across all learning styles.

## (c) Comparison of Mathematical Connection Skills

Table 5. Results of the mathematical connection ability between classes

Data	X IKM 1		X IKM 4	
	Pretest	Posttest	Pretest	Posttest
Mean	24,6	71,2	21,6	65,3
Standard Error	1,9	1,6	2,0	1,3
Median	24,0	70,0	20,0	63,3
Minimum	12,0	60,0	12,0	56,7
Maximum	48,0	96,7	48,0	83,3

Table 5. In class X. IKM 1, the average pretest score is 24.6 and posttest 71.2, indicating PBL learning in groups. Class X. IKM 4 class showed a pretest of 21.6 and a posttest of 65.3, but lower than X. IKM 1. Group *problem-based learning is more effective than paired problem-based learning*. Data variability showed a decrease in standard deviation, indicating more homogeneous student abilities. Data distribution tends to be normal, with most students improving. Overall, PBL improved mathematical connection skills, especially in group learning.

## 3. Inferential Statistical Analysis

## (a) Hypothesis Test 1

Before analyzing the covariance (ANCOVA) test, a prerequisite test was first conducted to ensure that all ANCOVA test requirements were met. After all assumption tests, such as the ANCOVA test requirements, have been met, the analysis of covariance (ANCOVA) test can be conducted. The hypothesis to be tested is as follows:

$H_0$  : There is no difference in the mathematical connection ability of students who are taught the PBL learning model in groups and those who are taught in pairs, in terms of students' learning styles.

$$(H_0: \mu_{\text{Cluster}} = \mu_{\text{Pair}})$$

$H_1$  : There is a difference between the mathematical connection ability of students who are taught the PBL learning model in groups and the PBL model in pairs, in terms of students' learning styles.

$$(H_1: \mu_{(\text{Cluster})} \neq \mu_{\text{Pair}})$$

Table 6. ANCOVA test

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	638,108 <sup>a</sup>	2	319,054	4,942	,010	,148
Intercept	38231,155	1	38231,155	592,171	,000	,912
PBL	564,120	1	564,120	8,738	,005	,133
Learning Style	64,153	1	64,153	,994	,323	,017
Error	3679,976	57	64,561			
Total	287169,820	60				
Corrected Total	4318,084	59				

In Table 6. Ancova test above that PBL [ $F(1,57)=8.378$ ,  $p = 0.005$ ,  $np^2 = 0.133$ ] this result is significant ( $p < 0.05$ ), so  $H_0$  in hypothesis 1 is rejected, which means there is a significant difference in mathematical connection ability between students taught with PBL models in groups and pairs. Thus, the learning model used, namely PBL (in groups or pairs), has a significant effect on mathematical connection skills, so that it can be concluded that the PBL model in groups and PBL in pairs has a different effect on students' mathematical connection skills.

(b) Hypothesis Test 2

Furthermore, the second hypothesis test is to determine the extent of the influence of learning style covariates on students' mathematical connection skills. The hypotheses tested are:

$H_0$  : There is no effect of learning style on mathematical connection ability at UPT SMAN 6 Jeneponto. ( $H_0 : \beta=0$ )

$H_1$  : There is an effect of learning style on mathematical connection ability at UPT SMAN 6 Jeneponto. ( $H_1 : \beta \neq 0$ )

The learning style value [ $F=(1,57)=0.944$ ,  $p=0.323$ ,  $np^2=0.17$ ] shows that the sig. The value is greater than the  $\alpha$  value of 0.05. Thus,  $H_0$  in the second hypothesis is accepted, and this indicates that learning styles (visual, auditory, and kinesthetic) have no significant effect on mathematical connection skills. This means that students' mathematical connection ability does not depend on their learning style.

### **Discussion**

1. Mathematical connection ability of students based on visual learning style.

Based on the results of the analysis, students with visual learning styles who were taught using the PBL group model showed a significant improvement in mathematical connection skills. In the pretest stage, the average mathematical connection ability of visual learners was 24.4, while in the posttest it increased to 69.7. This increase shows that the group PBL model is effective in helping students connect mathematical concepts with real situations. Learners tend to understand the material more easily through diagrams, pictures, and visual representations, which are provided in the grouped PBL model. This is in line with the theory of DePorter & Hernacki (2014), which states that visual learners learn more effectively through vision and visual representations. In the group PBL model, learners are given the opportunity to relate mathematical concepts to real situations through visual media provided in the LKPD. This supports the findings of NCTM (2000) that mathematical connections can be improved when learners are able to connect mathematical ideas with visual contexts. In addition, the significant increase in students' mathematical connection skills is also in accordance with the research of Kadir et al. (2020), who found that PBL is effective in improving mathematical connection skills through a contextual approach.

Learners with visual learning styles taught using the paired PBL model also showed an increase in mathematical connection skills. In the pretest, the average mathematical connection ability of learners was 26.8, and in the posttest, it increased to 65.3. Although this increase was significant, the result was slightly lower than the group PBL model. This may be due to the lack of variety of visual representations in the paired model, which emphasises the interaction between two people. However, learners can still utilise the diagrams and pictures provided in the LKPD to understand mathematical concepts. Nevertheless, this result still supports Aisyah & Usdiyana's (2022) research,

which found that PBL is effective for improving mathematical connections, although with different intensities depending on group organisation.

## 2. Students' mathematical connection ability based on auditory learning style.

Learners with auditory learning styles also showed an increase in mathematical connection skills after applying the PBL model in groups. In the pretest, the average mathematical connection ability of learners was 26.0, and in the posttest, it increased to 69.4. Although this improvement was significant, learners tended to be slower in understanding the material than visual and kinesthetic learners. This may be due to the lack of emphasis on the auditory aspect in the group PBL model. This finding is similar to Hidayati & Jahring's (2021) research, which states that auditory learners need more verbal stimulation to achieve optimal results. However, collaboration in groups allows learners to discuss and listen to explanations from group mates, thus still helping to improve their mathematical connection skills, as revealed by Hmelo & Barrows (2006) that PBL encourages effective collaboration skills.

Learners with auditory learning styles who were taught using the paired PBL model showed an increase in mathematical connection skills from 18.0 in the pretest to 64.2 in the posttest. This increase shows that the paired PBL model is effective in helping learners understand mathematical concepts through discussion and verbal explanation with their partner. However, this improvement is slightly lower compared to the group PBL model, possibly due to more limited interaction in the paired model. The increase in auditory learners suggests that discussion in pairs can be an effective alternative, although not as intense as in large groups. This is consistent with Hamzah's theory (in Habbab, 2024) that paired learning changes the role of learners from passive to active. However, this finding is slightly different from Siregar & Surya's (2017) research, which emphasises the need for more interaction for auditory learners.

## 3. Students' mathematical connection ability based on the kinesthetic learning style.

Learners with kinesthetic learning styles showed the highest improvement in mathematical connection skills after applying the PBL model in groups. In the pretest, the average mathematical connection ability of learners was 25.2, and in the posttest, it increased to 73.7. This increase shows that the group PBL model is very effective for learners who tend to learn better through physical activity and hands-on practice. In groups, learners can be actively involved in experiments and simulations, which helps them understand mathematical concepts more deeply. This is in line with DePorter & Hernacki's (2014) theory that kinesthetic learners learn more effectively through physical activity and hands-on experience. This finding is consistent with Hana & Sulistyorini's (2021) research, which states that kinesthetic learners excel in activity-based learning.

Learners with kinesthetic learning styles taught using the paired PBL model showed an increase in mathematical connection skills from 18.5 on the pretest to 65.0 on the posttest. Although this improvement was significant, the results were slightly lower compared to the group PBL model. This may be due to the lack of space for physical activity in the paired model, which emphasises verbal interaction and collaboration between two people. However, learners can still utilise the practical activities provided in the LKPD to understand mathematical concepts. The lower results compared to group PBL suggest that the limited space for movement in pairs reduced the effectiveness for kinesthetic learners. DePorter & Hernacki's (2014) theory states that kinesthetic learners need more space for exploration. This finding reinforces the research of Kenedi et al.

(2019), who suggested using learning models with higher physical activity for kinesthetic learners.

#### 4. Comparison of Group and Paired PBL Learning

Research by Kadir et al. (2020) found that the PBL model significantly improved students' mathematical connection skills compared to traditional learning methods. The results in this study are in line with the findings of Kadir et al. (2020), where the PBL model in groups and pairs also improves students' mathematical connection skills. This study also added that the group PBL model was more effective than the paired PBL model.

The research by Aisyah & Usdiyana (2022) in this study concluded that PBL is effective in improving students' mathematical connection skills, especially in flat and spatial building materials. The results of this study also show that PBL is effective for improving mathematical connection skills in statistics material. However, the study did not find a significant effect of learning style, which is different from some previous studies, which state that learning style can affect learning outcomes. The results of this study reinforce the findings of Kadir et al. (2020) and Aisyah & Usdiyana (2022) on the effectiveness of PBL in improving mathematical connections. However, this study makes a new contribution by comparing group and paired PBL, which has not been widely explored in previous studies. The findings also support the NCTM (2000) theory that mathematical connections require a collaborative and contextualised approach.

## CONCLUSION

Based on the results of the analysis and discussion, the conclusions obtained in this study regarding the effect of *problem-based* learning on mathematical connection skills in terms of learning styles at UPT. SMAN 6 Jeneponto is as follows: 1) The group *problem-based learning* (PBL) model proved to be more effective in improving students' mathematical connection skills compared to the paired PBL model. This can be seen from the increase in the average value of mathematical connection skills, which is more significant in classes that use the PBL model in groups. 2) Learning style does not have a significant effect on students' mathematical connection skills. Although the learners had different learning styles (visual, auditory, and kinesthetic), the PBL model was still effective in improving their mathematical connection skills. This shows that the PBL model can be adapted for various learning styles. 3) The increase in mathematical connection ability occurred in all learning styles, with the highest increase found in learners with kinesthetic learning styles who used the PBL model in groups. This shows that physical activity and collaboration in groups are very helpful for kinesthetic learners in understanding mathematical concepts. 4) The paired PBL model also provided significant improvement, although not as much as the group PBL model. This model is more suitable for learners who need intensive interaction in small groups, such as learners with auditory learning styles.

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