A meta analysis study: is Problem Based Learning (PBL) effective toward students’ mathematical connections ability?

S Aisyah 1,*, D Usdiyana 2
1Mathematics Education Study Program, School of Postgraduate, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
2Mathematical Education Department, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
*Corresponding Author
E-mail: aisyahsiti60@upi.edu

Abstract. PBL has become a popular topic in educational research studies. Several studies examine the effect of PBL toward students' mathematical connection abilities. A total of 8 articles qualified for inclusion. This study analyzed them using Meta Analysis with the Comprehensive Meta-Analysis (CMA) application by selecting the Hedge’s equation to determine its effect size and bias publication was assessed by the funnel plot, and Rosenthal’s fail-safe N (FSN) test. Based on the analysis result, the overall effect size is 0.797 according to random-effect model with a 95% confidence interval (CI). It was classified as a moderate level. The findings of the study showed that the overall implementation of PBL had a larger positive effect significantly compared to conventional learning on the students' mathematical connection's ability. Because, in the implementation of the PBL model, students are faced with problems that are closely related to everyday life. This shows that mathematical connection ability is needed one of which is the aspects of the connection between mathematics and daily life. Doing this research can support the development of learning and can be an alternative learning model to improving students' mathematical connections ability.

1. Introduction
According to the National Council of Teachers Mathematics (NCTM) [16] there are 5 (five) process standards in acquiring and applying content knowledge. The five process standards are 1) problem solving; 2) reasoning; 3) communication; 4) connection and 5) representation. Mathematical connections ability is very important for students because 1) when students can connect mathematical ideas, their understanding is deeper and more lasting [17], 2) as an instrument of problem solving, and 3) provides learning experiences, fosters confidence, and a higher awareness of mathematical benefits [9]. For this reason, teachers need to determine learning strategies and learning models that can improve students' mathematical connection ability. One appropriate learning model is (PBL) [9].

PBL has been successfully implemented in numerous disciplines for more than 30 years [10]. Problem-Based Learning is a learning model approach to the problem of authentic student learning so that students can construct their own knowledge [19]. Students can analyze, conduct investigations, link ideas or concepts that students have received so far and collect information related to problems so that students can find final solutions in mathematical problems [7].

The implementation of PBL model has become a popular topic in educational research studies. There are several studies doing research on the effect of PBL on students' mathematical connection ability (J01-J08). However, no study has further analyses on the implementation of PBL toward students' mathematical connection ability that note the study characteristics such as sample size,
sampling technique, restricted area sample, education level and year of publication that may also affect students' mathematical connection ability. On the other hand, educational practitioners need convincing conclusions that under what conditions PBL is effective toward students' mathematical connection ability. Thus, when there is a need to draw general conclusions, it is necessary to take into account the results of various individual studies using meta-analysis methods [28,30].

Meta-analysis is seen as a popular way to combine results from several primary studies, compare multiple treatments [34], summarize and explain them more widely [8]. Meta-analysis uses the study's effect size to produce the same empirical conclusions. This process includes calculating the mean effect, heterogeneity test and detecting moderator variables to explain the heterogeneity that characterizes meta-analysis studies [22]. The purpose of this study was to determine the magnitude of PBL effects toward students' mathematical connection abilities, and to research the extent that study characteristics moderate the effectiveness of PBL. This explanation shows the importance of conducting a comprehensive meta-analysis on the effectiveness of PBL in Indonesia for the last 10 years (2012-2021) toward mathematical connection ability. It is necessary to evaluate their use and see the overall trend more clearly.

2. Methods
This study uses meta-analysis. Like the general meta-analysis stages that have been applied [2,3,20], this study follows a similar stages, namely determine inclusion criteria; literature search and data coding; evaluate study quality; analysis statistic and make interpretation.

2.1. Inclusion Criteria
There are several standard eligibility criteria included in this meta-analysis that are used to filter empirical data, namely: 1) in the form of national and international journals or proceedings, thesis and dissertations; 2) publications have been carried out in the last 10 years (2012-2021); 3) using experimental or quasi-experimental research with an experiment class using PBL and the control class using conventional learning; 4) publications have statistical information as mean, standard deviation, sample size, t-value, and p-value.

2.2. Literature Search
The main study literature search was carried out by accessing the Google Scholar data base, Education Resources Information Center (ERIC), Directory Open Access Journal (DOAJ), and IOP Science. The search was carried out on the database using the keywords “problem based learning” and “mathematical connection ability”. The selection of the primary study was based on predetermined inclusion criteria. The primary study selection process went through four stages guided by PRISMA (Preferred Reporting Items for Systematic review and Meta-Analysis) [12], namely: 1) identification; 2) screening; 3) eligibility; and 4) included.

2.3. Statistic Analysis
Statistic analysis of this study, namely: 1) calculate the effect size of each qualified primary study and combined effect size; 2) conduct a heterogeneity test and select an estimation model; 3) check the publication bias; and 4) calculate the p-value to test the research hypothesis [28,30]. In this study, statistical analysis calculations were carried out with the help of Comprehensive Meta-Analysis (CMA) Software. In this meta-analysis study, Cohen’s classification has been used to interpret effect size (Hedges’ g) values [13]. Cohen’s effect size classification was used in this study [4,26]. Cohen's effect size classification is presented in Table 1.

| Effect Size (ES) | Classification   |
|------------------|------------------|
| 0.00 ≤ ES < 0.20 | Ignore           |
| 0.20 ≤ ES < 0.50 | Small            |
Effect Size (ES) Classification

| Effect Size (ES) | Classification |
|------------------|----------------|
| 0.50 ≤ ES < 0.80 | Moderate       |
| 0.80 ≤ ES < 1.30 | Large          |
| 1.30 ≤ ES       | Very Large     |

Heterogeneity test was performed to determine the effect model used in analyzing these studies. By checking the Q statistic or p-value. If p-value < 0.05, then $H_0$ states that homogenous of the effect size in this study was rejected. Therefore, the estimation model used was a random-effect model [14]. However, if p-value > 0.05 then $H_0$ is accepted and the estimation model for this analysis was a fixed-effect model. Finally, if the heterogeneity test result showed that the effect size of these studies was different, it was necessary to analyze several characteristics of samples and publication (moderator variable) that were likely to affect heterogeneity of these effect size [24].

Then, analyze publication bias, it is definitely necessary in meta-analysis studies [32]. Publication bias was used to examine whether there is a tendency of journals to publish only significant studies, leading to meta-analysis that did not represent the population [2,3]. Different techniques should be applied to determine publication bias and to estimate the degree to which it affects results [33]. As a result, initially the Funnel Plot approach was applied to analyze publication bias about literature contained in the meta-analysis [32]. There is no publication bias if the study effect size distribution is symmetrical between vertical lines [2].

Next, analyze publication bias use Rosenthal fail-safe N (FSN). Research is said to be resistant to publication bias. If the FSN value / (5k + 10) > 1 where (k represents the number of studies included in this meta-analysis) [6,15]. Then the p-value is needed in hypothesis testing to show the effectiveness of the PBL model on students' mathematical connection abilities.

3. Results and Discussion

Based on the research literature search results through the Google Scholar database, Education Resources Information Center (ERIC), Directory Open Access Journal (DOAJ), and IOP Science, thus only 8 primary studies met the inclusion criteria and qualified to be involved in this meta-analysis study process.

Data results from 8 primary studies [1,5,11,18,21,23,25,27] used in this meta-analysis can be seen at Table 2.

| Study Name (Authors) | PBL Pretest | Postest | CL Pretest | Postest | t-value/ p-value |
|----------------------|------------|---------|------------|---------|-----------------|
| J01 Fitri Rohaly, etc | 2.72       | 2.03    | 11.44      | 2.78    | 9.71            | 3.02            | 24               |
| J02 Wulan Nuraeni, etc | 5.44       | 4.84    | 28.84      | 15.06   | 22.53           | 13.28           | 32               |
| J03 Keuis Letti Setiawati | 9.42      | 2.13    | 22.86      | 4.422   | 15.167          | 3.613           | 36               |
| J04 Sri Sugiarti, etc | 4.25       | 2.56    | 14.08      | 2.96    | 12.72           | 2.72            | 36               |
| J05 Eka Firmansyah, etc | 6.85       | 3.37    | 87.4       | 9.85    | 74.65           | 14.42           | 15               |
| J06 Abdul Kadir, etc | 80         | 8.73    | 25         | 73.81   | 8.6             | 25              |                  |
| J07 Andi Susanto     | 68.93      | 14.13   | 30         | 62.43   | 15.22           | 30              |                  |
| J08 Dian Apriani     | 37         |         |            | 37      | 5.186           |                 |                  |

Note: SD (Standard Deviation); SS (Sample Size); PBL (Problem Based Learning); CL (Conventional Learning)

Data in Table 2. these are used to determine the effect size model, the heterogeneity test was performed. The results of the heterogeneity test from the studies conducted is shown in Table 3.
Table 3. The heterogeneity test result.

| Model     | n  | Hedge’s g | Standard Error | 95% CI      | Q       | P       | Decision |
|-----------|----|------------|----------------|-------------|---------|---------|----------|
| Fixed     | 8  | 0.761      | 0.096          | [0.574:0.949]| 28.512  | 0.000   | Reject $H_0$ |
| Random    | 8  | 0.797      | 0.195          | [0.415:1.179]|         |         |          |

The heterogeneity test results ($Q = 28.512; p = 0.000 < 0.05$) showed that effect size distribution was heterogeneous and indicated that the meta-analysis model of the study fitted to the random effects model. Thus, the random-effect model was significantly better than the fixed-effect model. The next analyze used a random-effect model as a basis for conducting the analysis [15]. Average value of effect sizes was calculated at 0.797. These findings were interpreted in the light of Cohen’s framework (Table 1) and it was found that PBL had positive effects towards students’ mathematical connection ability compared to conventional learning. This effect is moderate level.

![Funnel Plot of Hedge’s Standard Error](image.png)

**Figure 1.** The Funnel Plot of Hedge’s Standard Error.

Next, analyze publication bias used the Funnel Plot approach. In Figure 1, shows that the effect size distribution from the 8 primary studies analyzed in meta-analysis studies was symmetric around the vertical line, meaning that effect size data carries a small risk of publication. The Rosenthal Fail-Safe N (FSN) test also helped to determined possible publication bias [29,31].

Table 4. The Result of The Rosenthal’s Fail-Safe N Test.

| Classic Fail-Safe N                  |
|--------------------------------------|
| Z-Value for observed studies         | 8.13594 |
| The P-value for observed studies     | 0.00000 |
| Alpha                                | 0.05000 |
| Tails                                | 2.00000 |
| Z for alpha                          | 1.95996 |
| Number of observed studies           | 8.00000 |
| Number of missing studies that would bring p-value to > alpha | 130.00000 |

Based on Table 4, with FSN value = 130, it is obtained $130/(5*8 + 10) = 2.6 > 1$, meaning that this study is resistant to publication bias. Thus, no studies need to be added or omitted in the analysis because of this bias.
The next step is to calculate the p-value to test the research hypothesis. This stage is carried out to determine the overall effectiveness of the PBL model based on the random-effect model. Table 5. The following are the results of the overall analysis.

Table 5. Overall Analysis Result Based on the Random-Effect Model.

| Estimation Model      | n  | Z    | p   | Effect Size | Standard Error | 95% CI   |
|-----------------------|----|------|-----|-------------|----------------|---------|
| Random Effect Model   | 8  | 4.086| 0.000| 0.797       | 0.195          | [0.415:1.179]|

Table 5. shows the results of the overall analysis, where the overall effect size is 0.797 which is categorized as a moderate level according to the classification in Table 1. Then the z-score is 4.086 with p value = 0.000, this indicates that the results of this study are significant at the level of p < 0.05. In other words, statistically the two variables tested are different from each other. Thus, the application of the PBL model resulted in a better effect size of students' mathematical connection ability compared to students who received conventional learning (CL).

In Table 6. It can be seen that the moderator variable based on the sample size, for the sample size \( \leq 30 \), the effect size value is obtained 0.649 which is included in the moderate level. If the sample size >30, the effect size value is obtained 0.909, it is included in the large level. A heterogeneity test was been applied in order to find whether there was a significant difference between effect sizes of the meta-analyzed studies according to sample size. The test results show that there was no significant difference between effect sizes of the studies (\( Q = 0.425; p = 0.514 > 0.05 \)). Accordingly, the effects of PBL towards students’ mathematical connection ability did not change according to sample size \( \leq 30 \) or 30.

Based on the sampling technique, random sampling has an effect size of 0.970, which is included in the large level, while purposive sampling has an effect size of 0.312, which is included in the small effect level. The test results of heterogeneity test show that there was significant difference between effect sizes of the studies (\( Q = 4.881; p = 0.027 < 0.05 \)). This means that the application of the PBL
model to students’ mathematical connection abilities is very effective and influential if the sampling technique uses random sampling. As indicated in Table 6, based on restricted area sampling, it was obtained that the Java area had an effect size of 0.793 which was included in the moderate level, while for the Sumatra area it had an effect size of 0.818 which was included in the large level. Then, the result of the heterogeneity test show that $Q = 0.003; p = 0.956 > 0.05$, it can be concluded that there is no difference between the average effect size between groups of sampling areas (homogenous). Thus, restricted area sampling has no effect on implementation of PBL to mathematical connection ability.

In accordance with the random effects model, average effect size value with regard to students’ mathematical connection ability in Table 6 was found to be 0.709 (moderate level) for junior high school and 0.976 (large level) for senior high school. The results of the heterogeneity test show that there was no significant difference between effect sizes of the studies ($Q = 0.212; p = 0.645 > 0.05$). From the findings, it may be said that the effect of PBL towards students’ mathematical connection ability when compared to conventional learning does not vary according to education levels.

Then, in Table 6, effect sizes according to year of publication of random effects models are as follows: in 2014 is 0.969, 2016 is 1.193, and 2020 is 0.812 which are included in the large level, in 2017 is 0.437 is included in the small level and the last in 2018 it has an effect size of 0.584 which is included in the moderate level. The test results of the heterogeneity test show that there was no significant difference between the effect sizes of the studies ($Q = 5.511; p = 0.239 > 0.05$). Accordingly, the effects of PBL towards students’ mathematical connection ability did not change according to year of publication.

The results showed that the implementation of PBL had a significantly greater effect than conventional learning toward students’ mathematical connection abilities. Because, in the implementation of the PBL model, students are faced with problems that are closely related to everyday life. This shows that mathematical connection ability is needed one of which is the aspects of the connection between mathematics and daily life. So that students’ insight into mathematics will be broader and not focus on just one content and context [35].

4. Conclusion
Meta-analysis conducted on 8 primary studies shows that the implementation of the PBL model has a significant positive effect on students’ mathematical connection abilities compared to conventional learning, with the effect size 0.797 (moderate level). Then, based on moderate variables, it is concluded that the sampling technique has a different effect on the implementation of this PBL model. Random sampling technique has a greater effect than purposive sampling.

Although, the findings in this study conclude that PBL has a great influence on students’ mathematical connection abilities, this is only supported by primary studies that can be reached using a predetermined database. There are still many related studies that have not been analyzed because the required statistical information is not sufficient. In addition, this study has not reached other characteristics that may be related to the effectiveness of the PBL model on students’ mathematical connection abilities. As a result, this finding does not mean to describe the overall effectiveness of the PBL model on students' mathematical connection abilities. The potential meta-analysis studies investigate the effectiveness of PBL with different moderate variables such as duration of implementation, learning materials, and others.

Acknowledgments
Thanks, and gratitude are conveyed to the Lembaga Pengelola Dana Pendidikan (LPDP) for financial support in this study and thanks to all authors of the primary studies for providing the information we needed in this study.
Reference

[1] Apriani D 2017 Pengaruh Pembelajaran Problem Based Learning terhadap Kemampuan Koneksi Matematis Siswa. *Nabla Dewantara: Jurnal Pendidikan Matematika* 2(1)15-24

[2] Borenstein M and Hedges L V 2009 Introduction to Meta-Analysis (first). WILEY A John Wiley and Sons, Ltd. Publication. https://onlinelibrary.wiley.com/doi/book/10.1002/9780470743386

[3] Borenstein M, Hedges L V, and Rothstein H R 2009 Introduction to Meta-Analysis (Issue January). John Wiley & Sons

[4] Cohen J 1988 Statistical Power Analysis for The Behavioral Sciences, 2nd Edition (Hillsdale:Lawrence Erlbaum)

[5] Firmansyah E, Meilinda P M, dan Khoirina D A M M 2020 Implementasi Model Pembelajaran Problem Based Learning untuk Meningkatkan Kemampuan Komunikasi dan Koneksi Matematis serta Self-Efficacy Siswa SMA *Pasundan Journal of Mathematics Education (PJME)* 10(2) 51-64. DOI 10.5035/pjme.v10i2.2784

[6] Fragkos K C Tsagris M and Frangos C C 2017 Exploring The Distribution for The Estimator of Rosenthal’s “Fail-Safe” Number of Unpublished Studies in Meta-Analysis. *J. Commun. Stat. - Theory Methods* 46(11) 5672–5684.

[7] Friska L C, Pargaulan S, and Mukhtar 2020 Differences in the Mathematical Connection Capabilities of Students Taught by Using Guided Discovery Learning and Problem Based Learning Models Assisted by Autograph Viewed from Students' Numerical Ability. *American Journal of Educational Research* 8(5) 293-298. DOI:10.12691/education-8-5-11

[8] Green S 2005 Systematic Reviews and Meta-Analysis. *Evidence-Based Medicine and Healthcare*, 46(6) 270–24. https://doi.org/10.1002/9781444345100.ch5

[9] Hidayah I and Kurniasyah D 2019 An Analysis of Mathematical Connection Ability Viewed from Students’ Questioning-Skills Through The Educational Tools In Connected Mathematics Project Learning Model. *UNNES Journal Of Mathematics Education* 8(1) 65–74. https://doi.org/10.15294/ujme.v8i1.25949

[10] Jabarullah N H and Hafezali I H 2019 The Effectiveness of Problem Based Learning in Technical and Vocational Education in Malaysia. *Education Training* 1(5) ISSN: 0040-0912

[11] Kadir A, Rohmad R, and Iwan J 2020 Mathematical Connection Ability of Grade 8th Students’ in term of Self-Concept in Problem Based Learning. *Journal of Primary Education*.9(3) 258-266. DOI: https://doi.org/10.15294/jpe.v9i3.37547

[12] Liberati A et al 2009 The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions *Explanation and elaboration J. Clin. Epidemiol* 62(10) e1–e34.

[13] Demirel M. and Dagyar M 2016 Effects of Problem-Based Learning on Attitude: A Meta-analysis Study *Eurasia Journal of Mathematics, Science & Technology Education* 12(8) 2115-2137 doi: 10.12973/eurasia.2016.1293a

[14] Mike W and Cheung L. (2015). Meta-Analysis. United Kingdom: John Willey & Son Ltd.

[15] Mullen B, Muellerleile P, and Bryant, B 2001 Cumulative meta-analysis: A consideration of indicators of sufficiency and stability *Personality and Social Psychology Bulletin* 27(11) 1450–1462. https://doi.org/10.1177/01461672012711006

[16] NCTM National Council of Teachers of Mathematics 1999 Curriculum and evaluation standards for school mathematics. New York: Routledge & Kegan Paul.
[17] NCTM National Council of Teachers of Mathematics 2000) Principle and Standards for School Mathematics. Reston, VA: NCTM.

[18] Nurcaeni W, Kiki N S E dan Alpha G 2018 Penerapan Model Problem Based Learning dalam Meningkatkan Kemampuan Koneksi Matematis Siswa SMP. Prosiding Seminar Nasional Matematika dan Pendidikan Matematika Sesiomadika p395-401

[19] Nurizaman 2017 The Use of Problem Based Learning Model to Improve Quality Learning Students Morals Journal of Education and Practice. 8(9) ERIC Number: EJ1138846

[20] Pigott T D 2012 Advances in Meta-Analysis. In Statistics for Social and Behavioral Sciences Springer New York Dordrecht Heidelberg London. https://doi.org/10.1007/978-1-4614-2278-5

[21] Rohal F, dan Agung P A 2018 Penerapan Model Problem Based Learning untuk Meningkatkan Kemampuan Koneksi Matematis Siswa SMP Prosiding Seminar Nasional Matematika dan Pendidikan Matematika Sesiomadika p49-55

[22] Sanchez-Meca J, and Marin-Martinez F 1998 Testing continuous moderators in meta-analysis: A comparison of procedures British Journal of Mathematical & Statistical Psychology 51, 311-326.

[23] Setiawati K L 2014 Meningkatkan Kemampuan Pemahaman dan Koneksi Matematis Peserta Didik Melalui Problem Based Learning Pasundan Journal of Mathematic Education (PJME) 4(1) 39-52

[24] Siddiq F and Scherer R 2019 Is There A Gender Gap? A Meta-Analysis of The Gender Differences In Students’s ICT Literacy Educ. Res. Rev. 27 205-217

[25] Sugarti S 2014 Pengaruh Model Pembelajaran Berbasis Masalah terhadap Kemampuan Koneksi Matematis Siswa dalam Pembelajaran Matematika Musharafa Jurnal Pendidikan Matematika 3(3) 151-158

[26] Suparman, Juandi D, and Tamur M 2021 Review of Problem-Based Learning Trends In 2010-2020 : A Meta-Analysis Study of The Effect of Problem-Based Learning in Enhancing Mathematical Problem-Solving Skills of Indonesian Students Journal of Physics: Conference Series 1772(1), 012103. https://doi.org/10.1088/1742-6596/1722/1/012103

[27] Susanto A dan Soni A 2017 Penerapan Model Pembelajaran Problem Based Learning dalam Pembelajaran Matematika di Kelas VIII SMPN 28 Padang Math Educa Journal 1(2) 225-236

[28] Tamur M and Juandi D 2020 Effectiveness of Constructivism Based Learning Models Against Students Mathematical Creative Thinking Abilities in Indonesia: A Meta-Analysis Study Pervasive Health: Pervasive Computing Technologies for Healthcare 1, 107–114. https://doi.org/10.4108/eai.12-10-2019.2296507

[29] Tamur M, Juandi D, and Adem A M G 2020 Realistic Mathematics Education in Indonesia and Recommendations for Future Implementation: A Meta Analysis Study. JTAM | Teor. Dan Apl. Mat 4(1) 17

[30] Tamur M, Juandi D, and Kusumah Y S 2020 The Effectiveness of the Application of Mathematical Software in Indonesia: A Meta-Analysis Study International Journal of Instruction 13(4) 867–884. https://doi.org/10.29333/iji.2020.13453a

[31] Turgut S and Turgut I G 2018 The Effects of Cooperative Learning on Mathematics Achievement in Turkey: A Meta-Analysis Study International Journal of Instruction 11(3) 663–680. https://doi.org/10.12973/iji.2018.11345a
[32] Ümit Kul and Sedef Çelik 2020 A Meta-Analysis of the Impact of Problem Posing Strategies on Students’ Learning of Mathematics Revista Românească pentru Educație Multidimensională 12(3) 341-368. https://doi.org/10.18662/rrem/12.3/325

[33] Üstün U and Eryılmaz, A 2014 A research methodology to conduct effective research syntheses: Meta-analysis Education & Science 39(174) 1-32 https://doi.org/10.15390/EB.2014.3379

[34] White I R 2015 Network meta-analysis The Stata Journal 4 951–985. https://doi.org/10.1177/1536867X1501500403

[35] HendrianaH, RohaetiE Edan Sumarmo U 2017. Hard Skills dan Soft Skill Matematik Siswa Bandung: PT Refika Aditama