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Meta-analysis Study: Effectiveness of Creative Problem Solving Model in Science Learning in Indonesia

Darmanella Dian Eka Wati[1,5], Festiyed Festiyed[2], Abdul Razak[3], Muhyiatul Fadilah[4]

[1] Universitas Negeri Padang, Padang, Indonesia; darmanella22dew@gmail.com
[2] Universitas Negeri Padang, Padang, Indonesia; festiyed@fmipa.unp.ac.id
[3] Universitas Negeri Padang, Padang, Indonesia; ar710322@gmail.com
[4] Universitas Negeri Padang, Padang, Indonesia; muhyifadilah@fmipa.unp.ac.id
[5] Universitas Mahaputra Muhammad Yamin, Solok, Indonesia; darmanella22dew@gmail.com

Abstract: Despite the great potential of the CPS model which is recognized as able to improve science learning, research related to how effective it is in Indonesia is still limited. This meta-analysis seeks to investigate the effectiveness of the Creative Problem Solving (CPS) model in science learning in the specific context of educational institutions in Indonesia. Using data from 14 articles consisting of 21 studies at various levels of education (elementary school, junior high school, high school and tertiary) and disciplines (Natural and Social Sciences, Physics, Biology, Chemistry), the main objective of this study is to measure the effectiveness of the overall CPS model in science learning in Indonesia. The findings of the analysis showed a statistically significant effect size (ES) of 1.939 (95% CI: 1.413 to 2.466, $p < 0.001$), which indicates a significant positive influence of CPS in the field of science in Indonesia. Further subgroup analyses demonstrate the specific strengths of the CPS model in the High School environment and in subjects such as Chemistry and Biology. In addition, the CPS model has been proven to be effective in improving creative thinking skills and problem-solving skills. Despite these promising results, the existence of substantial diversity among studies underscores the need for additional research to determine the variables that influence the differences in outcomes. These findings provide support for integrating CPS in science learning with the aim of enriching student engagement and academic outcomes.

Keywords: Creative problem solving; Science learning; Meta-analysis

1. INTRODUCTION

Science education is one of the fields that has an important role in developing students' cognitive and practical skills, helping students by facilitating them with the tools they need to understand and interact with the world effectively. Quality science education is urgently needed in Indonesia, especially those that contribute to the development of a population that is literate in science and able to cope with complex global problems. Conventional learning used in science learning, characterized by memorization and passive learning, has been criticized because of its inability to engage students meaningfully and foster deep understanding. As a result, there is a high interest in innovative learning strategies that can improve student engagement and learning outcomes.

One of the innovative strategies is the Creative Problem Solving (CPS) model. Originally formulated by Alex Osborn and later refined by Sidney Parnes, the CPS model aims to foster creativity and analytical thinking by guiding students through systematic procedures in identifying problems, generating ideas, and implementing solutions (Isaksen et al., 2011). In the field of science education, CPS has the potential to offer learners practical, inquiry-driven opportunities that promote exploration, experimentation, and utilization of scientific principles in addressing real-world challenges. The CPS model integrates problem-solving skills with creative thinking processes (Julianto et al., 2022).

Despite the great potential of this CPS model which is recognized as able to improve science learning, research related to how effective it is in Indonesia is still limited and fragmented. Previous studies have concentrated more on small-scale, individualized classroom interventions, which have shown promising results but have lacked a comprehensive understanding of the impact of this model at different levels of education. In addition, existing research shows a variety of methodologies, thus hindering the ability to draw universally applicable conclusions about the effectiveness of CPS in improving science learning outcomes.

To overcome this gap, this meta-analysis seeks to systematically evaluate and synthesize existing research to determine the effectiveness of the CPS model in science education in Indonesia. By combining data from various studies, this meta-analysis research tries to provide a thorough and nuanced insight into how effective the CPS model is in science learning. The uniqueness of this study can be seen from the methodological rigor and specificity of the research focus on the educational landscape in Indonesia. This study seeks to explore the application of CPS in science education in Indonesia. This focus is particularly important due to the diverse cultural, socio-economic, and Indonesian backgrounds, which can affect the implementation and effectiveness of CPS in different ways than other contexts. The main objectives of this study are 1) to determine the overall

effectiveness of the CPS model in improving science learning in Indonesian schools. 2) to compare the effectiveness of CPS on several moderator variables (such as school level, subject, and student skills). 3) to provide evidence-based recommendations for educators and policymakers on the application of CPS in science learning. This study seeks to answer several research questions, namely: 1) what is the size of the effect of the CPS model on science learning outcomes in Indonesian schools. 2) how to compare the effectiveness of CPS on several moderator variables (such as school level, subject, and student skills). 3) what evidence-based recommendations can be provided to educators and policymakers about the implementation of CPS in science curricula.

This meta-analysis makes a significant contribution to the field of science education in Indonesia and its surroundings. Especially through the collection of existing researches, this study presents a more coherent and inclusive understanding of the influence of CPS on science education outcomes. Educators can leverage these findings to improve their teaching approaches, ensuring that students get the most out of CPS activities. In addition, by examining situational variables that moderate the effectiveness of CPS, this study underscores the importance of tailoring educational interventions to suit the different needs and situations of diverse student groups. The evidence-based suggestions gleaned from these meta-analysts can guide policymakers to support the integration and expansion of CPS in Educational Institutions, enrich science education and foster groups of creative, problem-solving students who are ready to face the challenges ahead, and support the development of innovative and analytical thinking.

2. METHODS

2.1. Research Design

This study uses a meta-analysis research design to systematically assess and combine existing empirical research on the effectiveness of the CPS model in the field of science education in Indonesia. Meta-analysis is a statistical method that combines findings from various studies to reveal overarching patterns and draw stronger conclusions compared to the conclusions produced by individual studies (Borenstein et al., 2009). Meta-analysis involves the results of research as a unit of analysis, specifically the results in the form of effect measures and meta-analysis is the analysis of the results of several studies, where individual studies are the unit of analysis (Card, 2012). This methodology allows for a thorough exploration of the effectiveness of the CPS model at various levels of education in Indonesia.

2.2. Literature Search Strategy

The strategies used for literature searches are carefully crafted to ensure comprehensive identification of all related studies. Searches were conducted on electronic databases such as Google Scholar, ERIC, Science Direct, Scopus, Taylor and Frances, and Wiley. The search terms used are "Creative Problem Solving Model" AND Science OR Biology OR Physics OR Chemistry AND Experimental OR Quasi Experiment. Manual checks are also carried out through a reference list of obtained articles and related review articles that are manually checked to determine additional studies that may have escaped those on the database. The inclusion criteria of this study are (a) to explore the effectiveness of CPS on science learning outcomes, (b) to be conducted in Indonesia, (c) to present adequate statistical data for the calculation of effect size, (d) to be published between 2014 and 2024. The sample selection technique uses purposive sampling techniques. This means that the data used as a sample is an article that has a relationship with the research variable in accordance with the inclusion criteria that have been set. Data analysis in this study uses descriptive statistics by calculating the effect size (ES) with the help of the OpenMEE application.

2.3. Data Extraction

The data extraction process is carried out using standard templates to ensure uniformity and accuracy. The details recorded from each study were the level of education (elementary school, junior high school, high school, higher education), research area (Indonesia), type of publication (International and National Journals, and Proceedings), science learning outcomes evaluated (creative thinking skills, problem solving, knowledge ability, skills, attitudes, learning outcomes, HOTS skills), and statistical data that are indispensable for the calculation of effect measures (number of sample, mean, and standard deviation). The grouping of effect size categories refers to (Cohen et al., 2022) as in table 1 below.

Table 1. Grouping of effect size categories using Cohen's interpretation

No	Classification	Interval
1	No Effect	$0.00 < ES \leq 0.19$
2	Small Effect	$0.19 < ES \leq 0.49$
3	Moderate Effect	$0.49 < ES \leq 0.79$
4	Large Effect	$0.79 < ES \leq 1.29$
5	Very Large Effect	$ES > 1.2$

The effect size was calculated to determine the effectiveness of Creative Problem Solving (CPS) on science learning outcomes using Hedge's g, which corrects the sample size bias. The calculation of the effect size for each outcome reported in each study was followed by aggregation. To address variability among studies, a random effects model was used, taking into account that the true effect size of CPS may differ across different educational settings and student populations. Assessments of heterogeneity among studies involved the use of Q statistics and I^2 statistics, with higher values indicating increased heterogeneity. Subgroup analysis was conducted to investigate potential moderator variables that affect CPS effectiveness, such as education level, field of study, and student skills.

3. FINDINGS AND DISCUSSION

Testing the effectiveness of the Creative Problem Solving (CPS) model in science education in Indonesia through meta-analysis was carried out on 14 articles consisting of 21 studies. These studies cover different levels of education (such as elementary school, junior high school, high school, and college) and a variety of subjects, including Physics, Biology, Chemistry and Science and Science. The results of data extraction and effect size measurements from each study can be seen in the following table 2.

Table 2. Hasil Ekstraksi Data dan Hasil Pengukuran Effect Size

Sudy ID	Ne	Xe	Sde	Nc	Xc	SDc	d	Var (d)	Reference
Study 1	35	68.257	17.5	36	53.472	10.476	1.017	0.064	(Andini et al., 2024)
Study 2	26	81.92	7.88	27	77.04	9.01	0.567	0.079	(Andrias et al., 2019)
Study 3	26	82.73	4.57	27	80.07	4.27	0.593	0.079	(Andrias et al., 2019)
Study 4	33	83.4	7.7	33	78.1	7.85	0.674	0.064	(Ariani et al., 2016)
Study 5	33	87.04	4.21	33	79.8	3.96	1.751	0.084	(Andrias et al., 2019)
Study 6	33	88.7	4.79	33	83.3	5.59	1.025	0.069	(Andrias et al., 2019)
Study 7	32	84.22	7.08	33	77.03	6.72	1.03	0.07	(M. R. L. Dewi & Putra, 2020)
Study 8	33	78	9.53	33	60.18	11.91	1.633	0.081	(Fatmawati et al., 2023)
Study 9	33	77	8.41	33	55.48	6.76	2.787	0.119	(Fatmawati et al., 2023)
Study 10	33	69.64	5.25	33	50.18	10.7	2.282	0.1	(Fatmawati et al., 2023)
Study 11	33	69.64	5.25	33	55.09	5.89	2.577	0.111	(Fatmawati et al., 2023)
Study 12	37	77.45	7.66	38	59.31	11.07	1.881	0.077	(Fitriyah et al., 2015)
Study 13	27	74.39	6.789	31	60.95	9.235	1.619	0.092	(Muhali, 2021)
Study 14	28	81.85	13.23	33	74.24	12.84	0.577	0.069	(Nurayiah et al., 2024)
Study 15	39	75.43	7.633	38	60.96	7.531	1.889	0.075	(Sugono et al., 2019)
Study 16	60	88.93	2.449	60	67.73	5.79	4.739	0.127	(Siska Widyaningtyas et al., 2024)
Study 17	60	87.93	2.196	60	66.3	4.484	6.088	0.188	(Siska Widyaningtyas et al., 2024)
Study 18	16	76.19	9	16	49.69	11.632	2.484	0.221	(Putri, 2021)
Study 19	36	58.46	6.23	36	28.15	7.97	4.192	0.178	(R. Dewi, 2022)
Study 20	23	78.43	6.178	23	71.14	4.871	1.288	0.105	(Rahayu et al., 2022)

Sudy ID	Ne	Xe	Sde	Nc	Xc	SDc	d	Var (d)	Reference
Study 21	30	75.4	15.9	30	64.5	16.44	0.665	0.07	(Shafina et al., 2020)

3.1. Results of Effect Size Measurement Analysis

The results of the standard meta-analysis test of 21 studies found that the overall effect size (ES) obtained from the continuous random effect model was 1.939 with a standard error of 0.269, which showed a statistically significant positive impact of the CPS model on students' understanding and skills in the field of science ($p < 0.001$). This proves what Donald J. Treffinger expressed that the CPS model improves students' creative and critical thinking skills. (Treffinger, 1995); (Nurrijal et al., 2023) (Susanti et al., 2023); (Fahrisa & Parmin, 2022). Likewise, several research results reveal that the CPS model can improve creative thinking skills (Rahmah Rezkiana et al., 2023); (Fatmawati et al., 2023). Creative Problem Solving Model improves problem analysis and solution development (Adeoye & Jimoh, 2023).

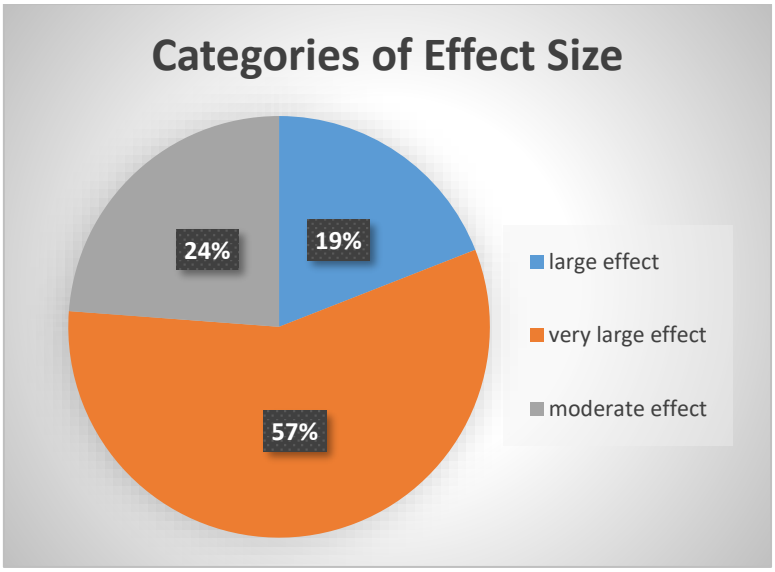

Figure 1. Grouping of effect study categories based on the results of meta-analysis of review articles

The measures of effect specific to each study showed striking variation, reflecting the diversity of results. Notably, Fatmawati's investigation from 2023 revealed very high effect measures (2,787, 2,282, 2,577), especially in fostering creative thinking skills within the field of Biology, which implies that the CPS model significantly improves creative thinking compared to traditional teaching methodologies (Fatmawati et al., 2023). Instead (Andrias et al., 2019) and (Ariani et al., 2016) documented a more moderate measure of effect (ranging from 0.567 to 0.674) in terms of physics knowledge proficiency, which indicates that although the CPS model proves to be beneficial, its effectiveness level may fluctuate based on the level of education, subject matter and skills assessed. The distribution of the effect size of the studied can be seen through the forest plot display in the following figure 2.

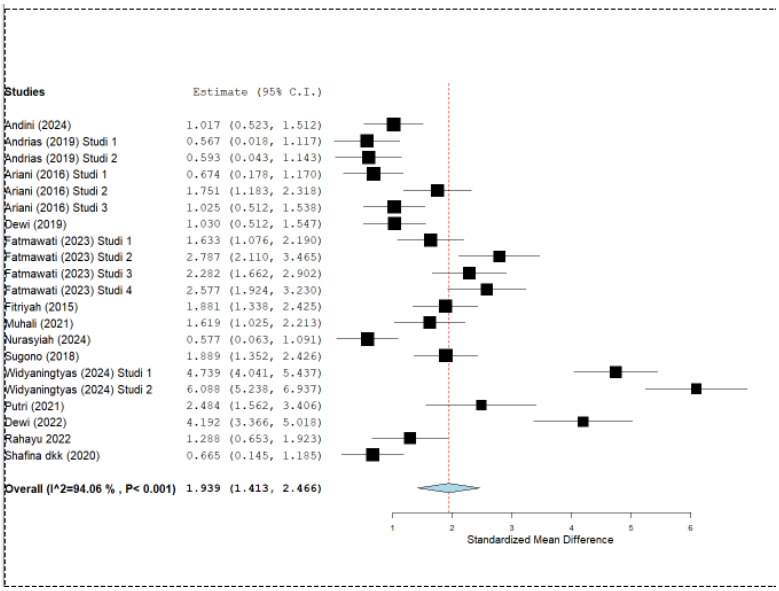

Figure 2. Forest Plot Results Summary Effect Size

Based on the forest plot image above, information was obtained that each black box represents the estimated effect of each study and the horizontal line that passes through the box shows the confidence interval of each study. The black boxes of the study that are in a position that does not cross the zero number show that the results of the study are statistically significant and the CPS model as a whole has a significant positive effect on science learning in Indonesia

3.2. Heterogeneity Test Results

The heterogeneity test in this study was carried out to determine whether the variance in the different study results was greater than expected. So that consistency can be assessed between the results of different studies. The data of the heterogeneity test results can be seen in the following table 3.

Table 3. Summary of heterogeneity test results and effect measures

tau^2	Q(df=20)	Het. p-Value	I^2
1.415	336.851	< 0.001	94.063

Based on the data in table 3, it is known that the tau2 value which is included in the category is quite large, this shows that there is a significant difference in the effect of CPS in various studies. A Q value with degrees of freedom (df) of 20 and a p-value<0.001 indicates that the observed heterogeneity occurs by chance, indicating that there is a significant variability between the results of the analyzed studies. The Diversity and Subgroup Analysis can be reviewed from the results of the diversity test is statistically quite large, while the value of I2 = 94.063%, shows that there is a considerable difference in the size of the effect between the studies. This indicates the presence of other factors that contribute to the variability in the results, such as differences in population and sample, or the context of CPS implementation.

The findings obtained from this meta-analysis show a strong and statistically significant impact of the Creative Problem Solving (CPS) model on science learning outcomes in Indonesia. Nevertheless, the very high level of heterogeneity shows substantial variation in the effectiveness of this model in a variety of contexts and studies. While CPS generally proves to be effective. Therefore, the implementation of CPS may need to be tailored to specific conditions to maximize its benefits.

3.3. Results of Subgroup Analysis of Moderator Variables

This diversity is further investigated through subgroup analysis, including 1) Education Level, 2) Field of study 3) Skills assessed. The results of the analysis of subgroups based on Education Level can be seen in the following table 4.

Table 4. Results Of Subgroup Analysis Of The Variables Of Moderators At The Education Level

Subgroup Education Level	Effect Size	Category
primary school	1.030	Large effect
Junior High School	1.973	Very Large Effect
High School	2.021	Very Large Effect
College	1.288	Large effect
Overall	1.939	Very Large Effect

Based on the data in the table above showing that the CPS model appears to be effective at all levels of education, the greatest measure of effect is seen in high school students, which suggests that the CPS model may be particularly beneficial at this stage of education. This is in line with the results of research conducted by Taliha which revealed that high school students showed higher creative problem-solving skills, while students showed advanced creative problem-solving skills (Keleş, 2022). The results of Sipayung's research revealed that Junior High School students showed low creative problem-solving skills (Sipayung et al., 2021). Meanwhile, Marta in her research revealed that Junior High School students showed moderate problem-solving skills (Martha et al., 2022). The transition period from primary school to junior high school can have an impact on creative problem-solving (Auliasari et al., 2021). The effectiveness of the CPS model is reviewed from the field of study, so the variation in effect size can be seen in the following table 5.

Table 5. Results of subgroup analysis of the moderator variables of the Education Level

Subgroup Education level	Effect Size	Category
Chemistry	2.889	Very Large Effect
Biology	1.939	Very Large Effect
Physics	1.863	Very Large Effect
Natural and Social Sciences	1.030	Very Large Effect
Overall	1.939	Very Large Effect

The effectiveness of the CPS model shows variation across different disciplines. Yet this CPS model is particularly effective in teaching Chemistry and Biology, perhaps due to the intrinsic characteristics of these subjects that are aligned with creative problem-solving strategies. The effectiveness of the CPS model also differs based on the skills of the students being evaluated. The difference in the size of the effect can be seen in table 6 below.

Table 6. Results of subgroup analysis of moderator variables students skills

Students Skill	Effect Size	Category
Problem solving	3.389	Very Large Effect
Creative Thinking	2.564	Very Large Effect
Attitude Competencies	1.751	Very Large Effect
Learning Outcomes	1.567	Very Large Effect
HOTS Skill	1.017	Large Effect
Konseptual	1.030	Large Effect
Competency Skills	0.821	Large Effect
Knowledge Competencies	0.639	Moderate Effect
Overall	1.939	Very Large Effect

Problem-solving ability shows the greatest measure of effect, meaning that students who learn with the CPS model become better at facing and solving complex problems, which is an important part of science learning. This is in line with research conducted by (Avina et al., 2022) that CPS has a high influence on problem-solving skills in students. The CPS model also has a very positive impact on developing students' creative thinking skills. This skill is important to invite students to think outside the boundaries of conventional

and create new solutions. The CPS model also has a positive impact on attitude competencies, knowledge, skills, learning outcomes, HOTS Skills and also students' conceptual abilities.

3.4. Funnel Plot Analysis Results

Funnel plot is a graphical tool used in meta-analysis to assess potential publication bias. This plot illustrates the relationship between the size of the study's effect and its satndar error. This plot depicts a distribution of points that tend to be more on the left side of the combined effect line and less on the right side. And there are a few points far to the right and bottom of the plot that show a higher effect size with a larger standard of error.

The distribution of effect sizes in the funnel plots shows some asymmetry, indicating potential publication bias. However, given the significant heterogeneity in the study, this asymmetry may also reflect a noticeable difference in the characteristics of the study rather than bias. The analysis of the funnel plot in this study showed a low risk of publication bias. This further strengthens confidence in the overall findings of the meta-analysis.

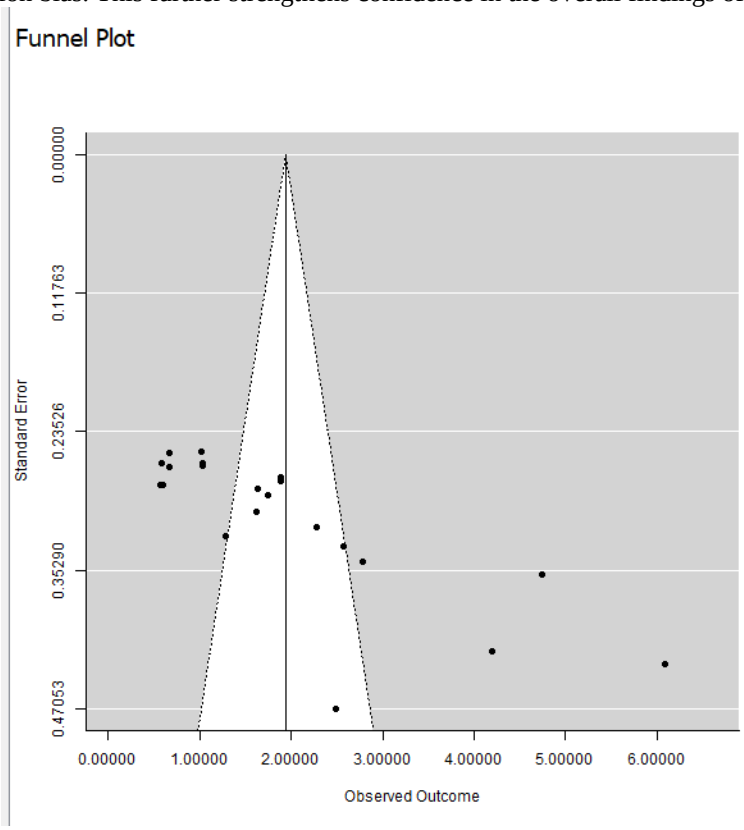

Figure 2. Funnel Plot Bias Publication

4. CONCLUSION

The meta-analysis conducted on the effectiveness of the CPS model in improving science learning in Indonesia showed a noteworthy positive effect, with an overall effect size of 1,939. In particular, this model shows its efficacy at the high school level, particularly in disciplines such as Chemistry and Biology, which encourages the development of innovative thinking and problem-solving abilities. The results of this study support the integration of the CPS model into the science curriculum as a means to enrich the learning experience and student achievement through the development of a more interesting, creative, and problem-solving-centered educational environment.

Nevertheless, the considerable diversity observed among the studies underscores the need for further investigation to determine the factors that contribute to the variation in results. Further research efforts should investigate aspects such as fidelity in applying the CPS model, teacher preparation, and student attributes to gain deeper insights into how to optimize the benefits of the CPS model in a variety of different educational contexts.

By placing an emphasis on creative problem-solving, the CPS model aligns with contemporary educational goals that aim to equip students with the skills necessary to navigate the intricacies of the 21st century, which not only fosters academic achievement but also the cultivation of fundamental life skills.

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