The Effectiveness of the Ethnochemistry-based Problem Based Learning Model on Students' Problem-Solving Ability in Chemistry Learning: A Meta-analysis Study in 2021-2024

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Abstract: This research is based on many ethnoscience-based problem-based learning studies on students' problem-solving skills. However, many different studies are related to drawing conclusions regarding the application of ethnochemistry-based project-based learning to students' problem-solving skills. This study aims to analyze the influence of ethnochemistry-based problem-based learning model on students' problem-solving ability in chemistry learning. Compared to conventional models. This research is a type of meta-analysis research. Data collection techniques through google scholar database searching; ERIC; ScienceDirect; Wiley; and IEEE. The research data was analyzed to calculate the effect size value of 17 primary studies that met the inclusion criteria. Data analysis with the help of JASP 0.16.3 software. The results of this study concluded that the ethnochemistry-based problem-based learning model had a significant influence on students' problem-solving ability with an mean effect size (d = 0.997; p < 0.001) including the high effect size category. These findings conclude that the ethnochemistry-based problem-based learning model is effective in improving students' problem-solving skills compared to conventional learning models. The results of the meta-analysis provide more accurate information so that it can improve the quality of chemistry learning for students at school.

Keywords: Effect size; Ethnochemistry; PBL; Problem solving

Introduction

Problem-solving skills are one of the skills that students must have in learning chemistry (Treepob et al., 2023; Afacan & Kaya, 2022). Problem-solving skills help students develop a deep understanding of scientific concepts as well as their real-life applications (Tessema et al., 2024; Özpunar & Arslan, 2023; Çetin et al., 2023). In addition, students' problem-solving skills are faced with various problems that require the application of theory to provide solutions in problem solving (Rahmawati et al., 2024). Therefore, students who have problem-solving skills are able to interpret data and conduct appropriately and can encourage students' higher-level thinking skills in learning chemistry.

Furthermore, problem-solving skills in chemistry learning motivate students to be more active and involved in the chemistry learning process (Kök & Duman, 2023; Kök & Duman, 2023; Zeng et al., 2023). Problem-solving skills are also very important in chemistry learning because they allow students to think critically and creatively. In chemistry learning, students are faced with a variety of situations that require innovative and effective solutions. Therefore, problem-solving abilities allow students to think creatively and find innovative solutions to the problems they face. Not
only that, problem-solving skills can help students develop critical and creative thinking skills.

Conventional chemistry learning models often focus on teaching chemistry concepts theoretically and do not provide opportunities for students to develop problem-solving skills (Jr & Cruz, 2022; Valdez & Bungihan, 2019). Thus, students can only remember and repeat the material without having the ability to apply those concepts in different situations (Tessema et al., 2024a). This can lead to students lacking the ability to think critically and develop effective solutions in dealing with complex chemical problems.

Chemistry learning also often does not provide opportunities for students to actively participate in the learning process (Kök & Duman, 2023). Students are only instructed to follow predetermined steps and are not given the opportunity to think critically and develop their own ideas. As such, students do not have the opportunity to develop effective problem-solving skills and do not have the ability to adapt to different situations (Tessema et al., 2024). Therefore, the conventional chemistry learning model needs to be changed in order to provide opportunities for students to develop effective problem-solving skills (Ningsih et al., 2023; Purwanto et al., 2022). Therefore, it is necessary to have a learning model that can encourage students' problem-solving skills in learning.

Problem-based learning is a learning model that focuses on developing students' abilities in dealing with complex problems (Rattanakha & Chatwattana, 2023; Siagian et al., 2019; Ernawati et al., 2022). In this model, students are given specific problems and instructed to solve them in a critical thinking and collaborative manner with classmates (Dakabesi & Luoise, 2019). Thus, students can develop problem-solving abilities that are chemistry learning.

The problem-based learning model can also help students develop soft skills such as teamwork, courage to think, and adaptability (Amin et al., 2020). In addition, the problem-based learning model gives students the opportunity to actively participate in the learning process and to develop their own ideas (Duda & Susilo, 2018; Wynn, 2022). Thus, students can develop effective problem-solving skills and have the opportunity to adapt to different situations (Amanda et al., 2022; Maksum et al., 2023; Nurlaily et al., 2019). Therefore, the PBL model can be an effective alternative in improving students' ability to face chemistry learning problems. However, the problem-based learning model can be combined with local culture, one of which is ethnochemistry.

Ethnochemistry is an ethnoscience related to problems related to chemistry (Singh & Chibuye, 2016). In the ethnochemistry-based problem-based learning model, students are given problems related to daily life related to local culture related to chemistry (Marasinghe, 2016). This teaching model allows students to develop their problem-solving, critical thinking, and communication skills, as well as have the opportunity to develop cultural awareness and concern for the environment. Previous research from Indonesia based on ethnoscience-based problem-based learning models can improve students' critical and creative thinking skills (Aristin et al., 2023; Ardianti & Raida, 2022; Yanto et al., 2023). In addition, the ethnoscience-based problem-based learning model can also improve learning outcomes and students' critical thinking skills in learning (Hikmawati et al., 2020). Research by Yuliana et al. (2021) stated that the ethnoscience-based problem-based learning model can improve students' science literacy.

Method

This research is a type of meta-analysis research. Meta-analysis is a type of research that quantitatively analyzes previous primary research (Martin et al., 2022; Li et al., 2022). This meta-analysis serves to evaluate the influence of ethnochemistry-based problem-based learning models on students' problem-solving abilities in chemistry learning. According to Borenstein et al. (2007), the meta-analysis research procedure consists of 1) determining the inclusion criteria of each study; 2) collecting and encoding research data and 3) analyzing data statistically can be seen in figure 1.

![Figure 1. Research procedure](image)

**Eligibility Criteria**

The research data included in this study must meet the inclusion criteria, namely 1) research data comes from SINTA and Scopus indexed journals; 2) The research was published in 2021-2024; 3) research must be experimental and quasi-experimental methods; The research was obtained through the Google Scholar database; ERIC; ScienceDirect; Wiley and IEEE; 4) The research must be open access and 5) the research presents complete results to calculate the effect size.
value. From the results of the data search, 17 applications that met the inclusion criteria were obtained which can be seen in (Table 2).

**Data Collection**

The data collection process in this meta-analysis comes from the google scholar database; ERIC; sciencedirect; Wiley and IEEE. The research data collected is related to the influence of ethnochemistry-based problem-based learning model on students' problem-solving ability in chemistry teaching. The keywords used are "problem based learning model"; "Problem based learning based on ethnochemistry"; "Ethnochemical-based problem-based learning on problem-solving skills"; and "Students' problem-solving skills in chemistry learning".

**Data Analysis**

The data analysis used in the meta-analysis study calculated the effect size value (Aybirdi et al., 2023). The effect size calculated is the magnitude of the influence of the ethnochemistry-based problem-based learning model on students' problem-solving ability in chemistry learning. According to Borenstein et al. (2007) the steps of data analysis in meta-analysis research are 1) calculating the effect size value of each study; 2) conducting data heterogeneity tests and determining estimation models; 4) testing publication bias and 5) p-value analysis to test research hypotheses. Furthermore, statistical analysis is carried out with the help of the JSAP application. The effect size criteria for this study can be seen in Table 1.

**Table 1.** Criteria for Effect Size Value (Borenstein et al., 2007)

<table>
<thead>
<tr>
<th>Effect Size</th>
<th>Effect Size Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.15 ≤ ES ≤ 0.15</td>
<td>No effect</td>
</tr>
<tr>
<td>0.15 ≤ ES ≤ 0.40</td>
<td>Small Effect</td>
</tr>
<tr>
<td>0.40 ≤ ES ≤ 0.75</td>
<td>Medium Effect</td>
</tr>
<tr>
<td>0.75 ≤ ES ≤ 1.10</td>
<td>Large Effect</td>
</tr>
<tr>
<td>0.10 ≤ ES ≤ 0.45</td>
<td>Very large effect</td>
</tr>
<tr>
<td>ES ≥ 1.45</td>
<td>Amazing Effect</td>
</tr>
</tbody>
</table>

**Result and Discussion**

Based on the results of the analysis of 17 studies that have met the inclusion criteria, effect size and error standard can be seen in Table 2. Based on Table 2, the analysis of the effect size value ranges from 0.49 to 2.13 and the standard error ranges from 0.16 to 0.52. According to the criteria of effect size value (Gignac & Szodorai, 2016; Borenstein et al., 2007), of the 17 effect sizes analyzed, there were three studies (17.64%) with medium criteria, five studies (29.41%) with large criteria, six studies (35.29%) with very large criteria, and three studies (17.64%) with Criteria Amazing's effect size.

Furthermore, an effective estimation model was determined to analyze the 17 effect sizes used as research data. The results of the analysis of the fixed and random models can be seen in Table 3.

**Table 2.** Effect Size and Standard Error

<table>
<thead>
<tr>
<th>Journal Code</th>
<th>Year</th>
<th>Effect Size</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK1</td>
<td>2024</td>
<td>1.32</td>
<td>0.34</td>
</tr>
<tr>
<td>PK2</td>
<td>2024</td>
<td>0.98</td>
<td>0.29</td>
</tr>
<tr>
<td>PK3</td>
<td>2021</td>
<td>2.13</td>
<td>0.47</td>
</tr>
<tr>
<td>PK4</td>
<td>2023</td>
<td>0.72</td>
<td>0.22</td>
</tr>
<tr>
<td>PK5</td>
<td>2023</td>
<td>1.18</td>
<td>0.37</td>
</tr>
<tr>
<td>PK6</td>
<td>2023</td>
<td>1.02</td>
<td>0.31</td>
</tr>
<tr>
<td>PK7</td>
<td>2024</td>
<td>0.81</td>
<td>0.28</td>
</tr>
<tr>
<td>PK8</td>
<td>2024</td>
<td>1.45</td>
<td>0.44</td>
</tr>
<tr>
<td>PK9</td>
<td>2022</td>
<td>0.76</td>
<td>0.21</td>
</tr>
<tr>
<td>PK10</td>
<td>2022</td>
<td>0.94</td>
<td>0.39</td>
</tr>
<tr>
<td>PK11</td>
<td>2021</td>
<td>1.23</td>
<td>0.47</td>
</tr>
<tr>
<td>PK12</td>
<td>2023</td>
<td>1.09</td>
<td>0.35</td>
</tr>
<tr>
<td>PK13</td>
<td>2021</td>
<td>2.04</td>
<td>0.52</td>
</tr>
<tr>
<td>PK14</td>
<td>2024</td>
<td>1.33</td>
<td>0.41</td>
</tr>
<tr>
<td>PK15</td>
<td>2024</td>
<td>0.66</td>
<td>0.18</td>
</tr>
<tr>
<td>PK16</td>
<td>2023</td>
<td>0.49</td>
<td>0.16</td>
</tr>
<tr>
<td>PK17</td>
<td>2023</td>
<td>1.28</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**Table 3.** Fixed and Random Effect Model

<table>
<thead>
<tr>
<th>Q</th>
<th>Dr</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omnibus test of Coefficients Model</td>
<td>53.316</td>
<td>1</td>
</tr>
<tr>
<td>Test of Residual Heterogeneity</td>
<td>157.779</td>
<td>16</td>
</tr>
</tbody>
</table>

Note: p-value are approximate
Notes: The model was estimated using restricted ML Methods

Table 3 the results of the Q value analysis of 157.779 are greater than 53.316 with a confidence level of 95%. This finding concluded that 17 effect sizes were heterogeneously distributed with a p < value of 0.001. Therefore, the effective model used to analyze the 17 effect sizes is the random effect model.
Furthermore, the publication bias of the 17 effect sizes analyzed was checked. Bias checking functions to find out whether there is a publication bias against the data entered. Publication bias checking using plot funnel analysis and Rosenthal Fail Safe N (Borenstein et al., 2007; Li et al., 2022; Aybiri et al., 2023). The results of publication bias analysis with funnel plot can be seen in Figure 2.

Based on Figure 2, the results of the effect size analysis with the funnel plot are difficult to know whether it is symmetrical or asymmetrical. Thus, it is necessary to carry out further tests of Rosenthal Fail Safe N. The results of the Rosenthal Fail Safe N test can be seen in Table 4.

**Table 4. Rosenthal Test Fail Safe N**

<table>
<thead>
<tr>
<th>File Drawer Analysis</th>
<th>Target Significance</th>
<th>Observed Significance</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosenthal</td>
<td>1161.000</td>
<td>0.050</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Table 4 the value k = 17 then (5k + 10) = 5(17) + 10 = 95. The Rosenthal Fail Safe N test score was 1161 with a target significance of 0.050 and p < 0.001. Because the Fail Safe N value > 5k + 10, this finding concludes that the effect size included is not biased in publication and can be scientifically accounted for. Furthermore, calculate the p-value to test the research hypothesis through mean effect size analysis. The results of the mean effect size analysis can be seen in Table 5.

**Table 5. Mean Effect Size**

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.997</td>
<td>0.298</td>
<td>10.165</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Table 5 the results of the mean effect size analysis with a random effect model obtained a mean effect size value of 0.997 with a standard error of 0.298. This finding is included in the large effect size. The results of the statistical calculation obtained a value of z 10.165 and p < 0.001. These results conclude that the ethnochemistry-based problem-based learning model has a significant effect on students' problem-solving ability in chemistry learning compared to conventional models.

This research is in line with Rusmansyah et al. (2023) that the ethnochemistry-based problem-based learning model can improve students' critical thinking and problem-solving skills in learning. The findings are in accordance with Yanto et al. (2023) that the ethnochemistry-based problem-based learning model in developing students' problem-solving skills and learning outcomes. Problem-based learning (PBL) that integrates ethnochemistry brings chemistry materials closer to students' real lives, using the local cultural context as a foothold in solving problems (Sudarmin et al., 2019). This model is designed to not only improve conceptual understanding of chemistry, but also to develop students' cognitive and metacognitive skills (Ernawati et al., 2022). Ethnochemistry that explores the relationship between chemical knowledge and cultural practices has the potential to be a powerful tool to make subject matter more relevant and increase students' motivation to learn.

In the ethnochemistry-based PBL model, students are required to analyze problems, identify relevant variables, and develop pragmatic solutions based on chemical knowledge (Winarto et al., 2022). Through this approach, students not only gain more in-depth knowledge of chemistry, but also learn to apply that knowledge in a broader and more diverse context, thus strengthening their ability to solve problems (Hikmawati et al., 2021). The application of ethnochemistry-based PBL model in chemistry learning shows significant potential in improving students' problem-solving skills. The relevance of chemical content to the local cultural context not only increases the relevance of the material, but also motivates students to be more active in the learning process (Yuliana et al., 2021). Despite the challenges, the benefits that can be gained suggest that more schools should consider adopting this model as part of their learning strategies. With the right adjustments and support, this model can be very effective in shaping students' critical thinking and analytical abilities in chemistry learning.

**Conclusion**

From the results of this study, it can be concluded that the ethnochemistry-based problem-based learning model has a significant influence on students' problem-solving ability with a mean effect size (d = 0.997; p < 0.001) including the high effect size category. These findings conclude that the ethnochemistry-based problem-based learning model is effective in improving students' problem-solving skills compared to conventional learning models. The results of the meta-analysis provide more accurate information so that it can improve the quality of chemistry learning for students at school. The integration of ethnochemical aspects in chemistry learning not only deepens students' understanding of the material, but also increases the social and cultural relevance of what they learn. Thus, students become more engaged and motivated to actively participate in the learning process, which ultimately helps them develop the critical skills necessary to apply chemical knowledge in real-life situations.
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Author Contributions
In the research, the author Hotmauli Gultom contributed to collecting, selecting and analyzing the results of the research. Second author: Eli Rohaeti contributed to providing input and criticism on the content of this study.

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Conflicts of Interest
The authors declare no conflict of interest.

References

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