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# Nurturing soft skills and metacognition awareness through STEAM project-based learning: A comprehensive need analysis

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A B S T R A C T

This study systematically analyzes educational literature using VOSviewer to explore the potential of developing STEAM Project-Based Learning (STEAMPjBL) for fostering soft skills and metacognitive awareness. Following the VOSviewer analysis, a needs survey was conducted with 36 lecturers and 232 students from Indonesia and Malaysia. This research uses a mixed-methods approach with an exploratory sequential design. Findings indicate a strong potential for STEAMPjBL to enhance students' soft skills and metacognitive awareness. Lecturer survey results highlight significant potential for STEAMPjBL development through collaborative networks among lecturers and institutions. Although most students were unfamiliar with STEAMPjBL, they expressed interest in using it in both classroom and extracurricular STEAM projects. From both the literature review and survey perspectives, the development of STEAMPjBL to promote soft skills and metacognitive awareness is essential.



## 1. Introduction

Effective education involves transferring knowledge and developing skills to face future challenges. In an era where technology continues to grow rapidly, education must be able to prepare future generations to become creative problem solvers, collaborate effectively, and have a deep understanding of their thought processes. One approach recognized for achieving this goal is the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach, which emphasizes the integration of scientific disciplines to build a comprehensive understanding. STEAM education can be effectively integrated into real-world projects to promote practical learning by implementing active project-based methodologies such as Project-Based Learning (Colucci-Gray and Burnard, 2020). Each STEAM discipline (Science, technology, engineering, arts, and mathematics) has interconnected pathways to build interdisciplinary/transdisciplinary learning tasks that foster students' deep understandings (Sickler-Voigt, 2023). It involves a paradigm shift seeking a balance between knowledge and transdisciplinary skills (Holbrook et al., 2020).

Project-based STEAM learning can be achieved through robotics-based models that engage students actively in STEAM disciplines, aiding 21st-century skills. By implementing project-based learning with robotics, students can have hands-on experiences applying theoretical knowledge, fostering critical thinking, creative thinking, and scientific process abilities (Conde et al., 2021a). Robotics-based models offer a practical approach to bridge the gap between theory and practice, enhancing students' learning outcomes in control theory and robotics techniques.

Some of the latest research on project-based STEAM learning models, namely enhancing project-based learning methods with differential-drive robots (Beuchat et al., 2022; Conde et al., 2020). The RoboSTEAM project uses robotics and physical devices to enhance computational thinking skills and competencies in diverse environments effectively (Conde et al., 2021b). Project-based STEAM learning can be implemented through affordable open-source robotics, DIY robots, and manufacturing tools for hands-on education (Montero, 2018). Project-based STEAM learning in robotics teaching models can provide practical application, foster problem-solving skills, and promote comprehensive talent

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development, critical thinking, technological skills, cooperative learning, creativity, and real-world problem-solving (Ding et al., 2019; Manera, 2020; Ruiz Vicente et al., 2020; Zayyinah et al., 2022).

Previously, no recent research had developed a project-based STEAM learning model for robotic learning to improve soft skills and metacognition awareness. Even though soft skills and metacognition awareness have the potential to determine the success of project-based learning. Incorporating soft skills training into project-based learning offers numerous benefits. Firstly, it enhances communication, teamwork, and project planning abilities. Secondly, it aids in developing traditional hard skills alongside necessary soft skills and visual-image engineering language proficiency (Daineko et al., 2022). Additionally, project-based learning provides a platform for students to learn challenging skills and concepts, including soft skills and system thinking, through hands-on projects (Shekh-Abed and Barakat, 2022). By integrating soft skills training into project-based learning, students can acquire a holistic skill set vital for professional growth and success.

Soft skills, such as communication, teamwork, problem-solving, and emotional intelligence, are innate abilities that individuals naturally possess. However, these skills can also be developed through formal training and practical experiences. Research emphasizes the importance of soft skills in today's rapidly changing environment, highlighting their significance in academic and real-world situations. Soft skills, such as teamwork, can be developed through formal training, as shown in the research on training for engineering students to enhance socio-emotional competencies like leadership and multiculturalism (Gruber et al., 2022).

Metacognition is necessary to understand the task's performance (Hartman, 2013). Flavell (1979) made the distinction between metacognitive knowledge and metacognition awareness. Metacognitive knowledge refers to explicit knowledge about our cognitive strengths and weaknesses. Metacognition awareness refers to our feelings and experiences when we engage in cognitive processes (Perfect and Schwartz, 2002). Conceptualizations of metacognition have in common that they take the perspective of higher-order cognition about cognition. These conceptualizations stress the supervisory role of metacognition in initiating and controlling cognitive processes (Zohar and Dori, 2011).

Various studies have shown that metacognition awareness can be effectively trained and transferred to real-world applications. Research has shown that metacognitive confidence judgments are crucial in intention offloading and subsequent fulfillment of real-world intentions (Scott and Gilbert, 2024). Metacognitive awareness can be trained and applied in real-world scenarios by understanding cognitive responses and coping strategies and enhancing motivation to overcome destructive risks effectively (Frolova, 2022). Additionally, metacognitive awareness is essential for transferring implicit knowledge between dissimilar tasks, with participants needing to be aware of the relevance of their experience for successful transfer (Ivanchei and Servetnik, 2023).

Incorporating metacognitive awareness into project-based learning offers several benefits. Firstly, it enhances students' critical thinking and problem-solving abilities, leading to better educational success (Widodo et al., 2023). Secondly, it improves students' metacognitive abilities, as observed through increased awareness and development in solving metacognitive problems. Integrating metacognition in project-based learning also promotes independent learning, peer learning, communication, collaboration, and feedback (Frolova, 2022). Moreover, the relationship between metacognitive involvement, cognitive style activities, and risk anticipation can predict maladaptive behaviors, highlighting the importance of metacognitive awareness in personal development. Incorporating metacognition awareness in project-based learning enriches students' learning experiences and fosters holistic cognitive growth.

Learning robotics in a STEAM context provides an ideal platform for developing these soft skills, as it involves the design, construction, and programming of robots that require collaboration, creativity, and perseverance. In project-based STEAM robotics learning, metacognitive awareness can help learners understand how they learn, evaluate their learning strategies, and make necessary adjustments to improve their understanding and performance. Thus, research on needs analysis in developing project-based STEAM learning models in robotics learning is important to ensure the relevance and effectiveness of learning approaches and to produce valuable insights into how education can improve students' soft skills and metacognitive awareness.

This needs analysis study will integrate a systemic literature review approach using VIOSviewer software to systematically and comprehensively analyze literature on developing project-based STEAM learning models. A systemic literature review approach with the use of VIOSviewer allows researchers to identify patterns of relationships between related concepts and identify research gaps that need to be filled (de Jong and Bus, 2023; Tovar and Reta, 2022; Choi et al., 2022). Using VOSviewer, researchers can visualize and map the connections between different concepts and identify key focus areas for future research. This method will be continued by surveying Indonesia and Malaysia to identify stakeholders' needs, students, and lecturers. The combination of these methods, known as the mixing method, will provide a deeper and more comprehensive understanding of the need for developing this learning model to improve soft skills and metacognitive awareness. Thus, the research questions included two main aspects: (1) what are the needs analysis results for developing a project-based STEAM learning model to improve soft skills and metacognitive awareness using VIOSviewer? (2) What are the results of the needs analysis for developing a project-based STEAM learning model from the perspective of students and lecturers in Indonesia and Malaysia?

## 2. Methodology

The research method used is a mixed method with an exploratory sequential design type that involves a quantitative data collection phase followed by a second phase of qualitative data collection (Creswell and Creswell, 2005). Qualitative data was obtained through a systemic literature review using VOSviewer, while quantitative data was obtained from surveys. The concept map of type exploratory sequential design is shown in Fig. 1.

### 2.1. Data validity

The validation of the survey instrument involved assessing both content validity and construct validity. Content validity was measured using the Aiken coefficient, while construct validity was evaluated through Confirmatory Factor Analysis (CFA). The survey questionnaire achieved content validity, as the Aiken coefficient, calculated with eight raters, resulted in a score of 0.85. The CFA results showed that $\chi^2$ = 2.5, which is favorable since it is below the commonly accepted cutoff value of 3. The Comparative Fit Index (CFI) was 0.93, indicating a good model fit as it exceeds 0.90. The Tucker-Lewis Index (TLI) was 0.91, which also reflects a good fit since it is greater than 0.90. The Root Mean Square Error of Approximation (RMSEA) was 0.06, signifying a good fit because it is less than 0.08. Additionally, the Standardized Root Mean Square Residual (SRMR) was 0.05, demonstrating an excellent fit since it is below 0.08. These results indicate that the CFA model aligns well with the data, supporting the construct validity of the survey instrument. The instrument's reliability was verified using Cronbach's Alpha, yielding a value of 0.76, which confirms the survey's reliability.

### 2.2. Data collection

Data collection in VOSviewer begins with identifying relevant data sources. The data source used in this research is Google Scholar, which has the theme "Potential for STEAM Project Development in Robotic Learning to Develop Soft Skills and Metacognition Skills," as shown in Fig. 1. Data was collected using the "Publish or Perish" application by entering the keywords STEM, project-based learning, soft skills, and metacognition awareness. The articles collected are limited to 2014-2023 (Fig. 2).

A summary of article search results in Publish or Perish is presented in Citation metrics as in Fig. 3.

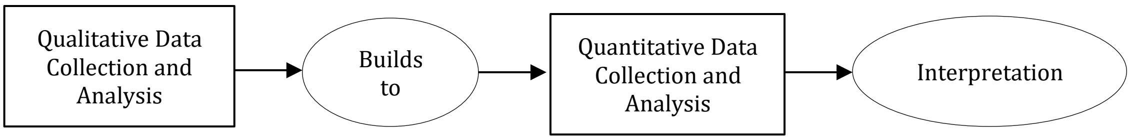


**Fig. 1:** The concept map of type exploratory sequential design

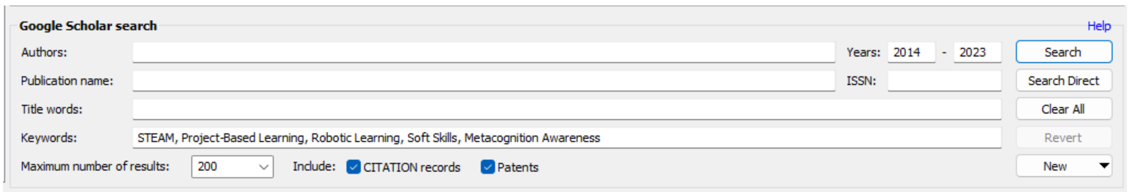


**Fig. 2:** Entering keywords and year range in Publish or Perish

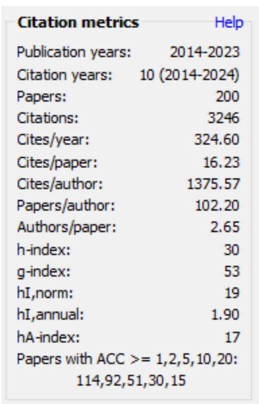


**Fig. 3:** Citation metrics publish or perish

Fig. 3 shows that the number of articles collected was 200 articles. The total number of citations for all articles is 3246. The annual citation number (cites/year) is 324.60, obtained from the total number of citations divided by 10 (range of years of publication). The citation rate per article (cites/paper) of 16.23 was obtained from the total number of citations divided by 200 (number of articles). The number of citations per author (cites/author) is 1375.57. The number of articles per author (papers/author) is 102.20. The number of authors per article (author/paper) is 2.65.

The H-index reflects the number of publications and the number of citations per publication. The number of citations from the accumulated articles cited influences other articles and can be used to calculate the g-index. The g-index calculation is the overall average number of quotes after sorting them to the number g. The weight of citations a document receives is considered in the g-index calculation. hI, norm is an individual h-index obtained from normalizing the number of citations for each article by dividing the number of citations by the number of authors for that article and then calculating the h-index of the normalized number of citations. Meanwhile, hl, annual is a number obtained from hl, which is the norm divided by academic age (the number of years in effect since the first publication).

Data collected in publish or perish is stored in the "ris" format. The data that has been saved is imported into the VOSviewer software with the following procedure: (1) select the create a map based on the text data menu. (2) select the read data from the references manager files menu. (3) select the title and abstract files menu. (4) select the binary counting menu. (5) Choose the minimum number of occurrence of terms, as 10 of the 1138 terms and 33 meet the threshold. (6) make the number of terms to be selected 15. (7) then verify the selected terms, as in Fig. 4.

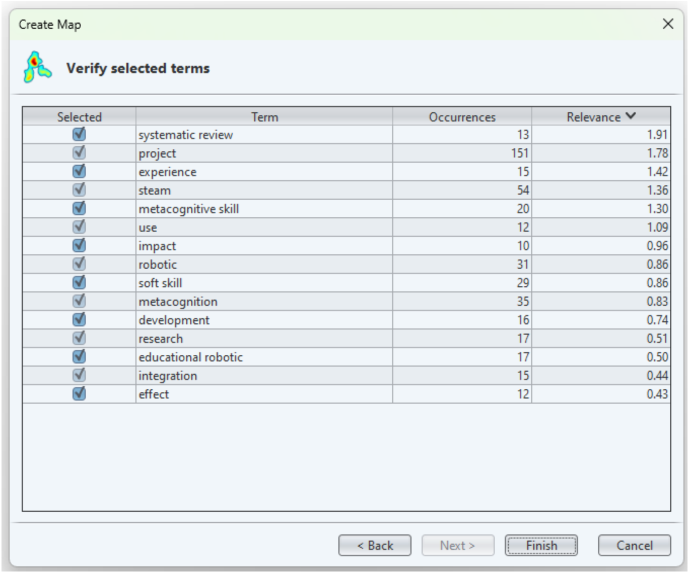


**Fig. 4:** Selected terms in VOSviewer

Network Analysis aims to identify relationships between concepts in the dataset. Network visualization parameters include node size and line thickness. Network analysis identifies strong relationships between concepts that may describe relevant patterns in the literature. Overlay analysis enriches understanding of the distribution of additional attributes in the dataset, such as the frequency of certain keywords or the number of article citations. It is carried out to identify the most influential or significant elements. Density analysis is used to identify areas in a network with a high or low density of certain elements. Results: The Identification of clusters or groups of concepts that may be formed based on density shows research opportunities that can be carried out on these clusters.

Survey data was collected through Online Surveys using Google Forms. The survey link was sent using WhatsApp. The advantages of online survey techniques are that they are more efficient, low-cost, and can reach a wide and diverse range of respondents.

## 2.3. Data analysis

Interpretation of results involves a comprehensive analysis to identify significant patterns, trends, and relationships in the dataset. After interpreting the results, we consider the findings regarding the potential for developing the STEAM Project in robotics learning.

A needs analysis survey for developing a project-based STEAM learning model was conducted in Indonesia and Malaysia. The participants consisted of students and lecturers. The sample was selected using a simple random sampling technique. The Slovin formula determines the sample size. Slovin's formula aids in achieving good sample selection by providing a systematic approach to calculating the ideal sample size based on the population size and desired level of precision. Using Slovin's formula, researchers can avoid biases caused by inadequate sample sizes and enhance the robustness of their research findings (Shorten and Moorley, 2014). Using the Slovin formula at an error rate (e) of 0.05, a sample of 268 comprised 36 lecturers and 232 students.

The data analysis procedure in this research uses the Miles and Huberman technique. This technique involves three main stages: data reduction, data presentation, and concluding/verification. Reduction is done to select data most relevant to the research question. Data presentation uses diagrams and tables to help see patterns and relationships between categories. Apart from that, the data is also presented through a narrative to describe the findings from the reduced data. Concluding is carried out to analyze the findings that have been presented and to draw conclusions about patterns, themes, relationships, or categories that emerge from the data.

## 3. Results

### 3.1. Systemic literature review results

The results of research using VOSviewer consist of three parts: network visualization, overlay visualization, and density visualization. These three types of visualization work together to provide a deeper understanding of the structure and patterns in the analyzed dataset. They help identify relationships, the distribution of attributes, and the degree of density of elements in the context of given data. Network visualization displays the relationships between elements in a dataset, usually as a graph or network. It helps identify clusters or groups of elements closely related to each other and elements that act as bridges between clusters. This network analysis can provide insight into the data's relationships and patterns. The network visualization in this research is presented in Fig. 5.

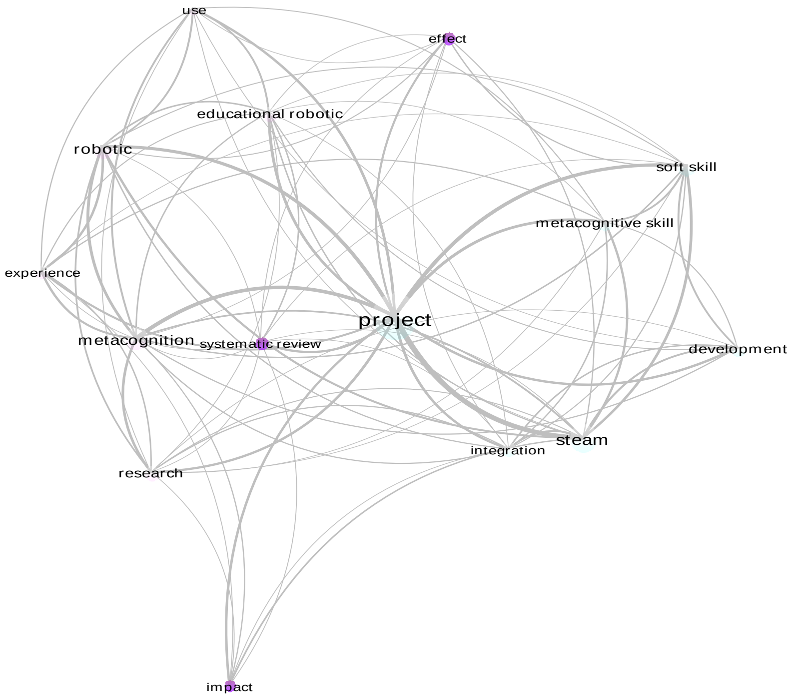


**Fig. 5:** VOSviewer network visualization

The first cluster in Fig. 5, consisting of development, integration, metacognitive skills, projects, soft skills, and STEAM, offers enormous potential for further research in various fields. In the last ten years, research on projects has become the focus, followed by research on STEAM. However, development, soft, and metacognitive skills still need adequate attention. The high research focus on projects suggests great interest in understanding how projects in educational contexts, particularly those related to STEAM approaches, can influence student learning and development. However, deeper research on competency development, both in terms of soft and metacognitive skills, is still an area that has yet to be fully explored.

The network in the second cluster, which consists of educational robotics, experience, metacognition, research, robotics, and use, as shown in Fig. 5, needs more research linking these elements. This highlights the existence of untapped potential in this field. Although each element may have its importance and relevance in the context of robotics education, the relationships between them still need to be explored in the scientific literature. The lack of research connections between elements in this second cluster represents a gap in the literature that could be filled with future research. Increased research in this field can pave the way for innovations in robotics education that are more effective and sustainable. By combining various aspects, such as practical experience, metacognition, and technology, this research can significantly contribute to our understanding of learning and teaching in educational robotics.

The third cluster, consisting of effect, impact, and systemic review, stands out as the least researched among the other clusters, as seen in Fig. 5. This suggests a significant need for more research exploring the relationships and implications of effects, impacts, and systemic overviews in various contexts. Although the elements in this cluster may be very relevant in evaluating and analyzing the impact of various interventions or innovations in education, research that directly links these elements still needs to be made available.

Filling the existing research gaps in this third group will expand our understanding of the complexity of interactions and the implications of various aspects in the educational context. Continued research in this area can provide a more comprehensive view of how educational approaches and policies influence student outcomes and learning experiences and how changes in one area can affect the system. Therefore, research that connects elements in the third cluster with other elements is essential to enrich knowledge and practice in education.

Overlay visualization shows the distribution or pattern of attribute presence over the elements in the dataset. This helps clarify the dataset's more significant elements based on the additional attributes provided. Overlay visualization can also show the frequency of appearance of certain keywords or terms in scientific articles or publications. It helps identify elements that have a greater impact or contribution to the overall dataset and enables a better understanding of the distribution of additional attributes in the data context. The results of the overlay visualization in this study are shown in Fig. 6.

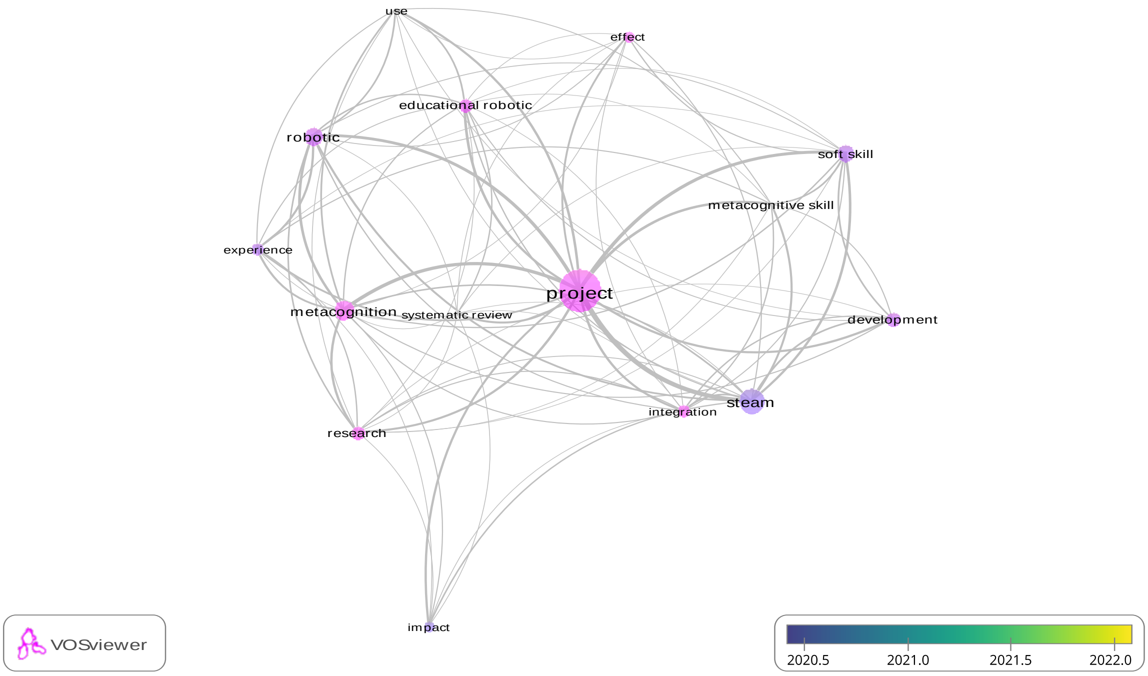


**Fig. 6:** VOSviewer visualization overlay

Density visualization shows the density or concentration of elements in a dataset in a certain area. It helps identify dense or isolated clusters and areas within the network that may require further attention in analysis. In a bibliometric context, density visualization can help find areas within a network that have a high concentration of articles or scientific publications relevant to a particular topic. Fig. 7 shows density visualization in this research.

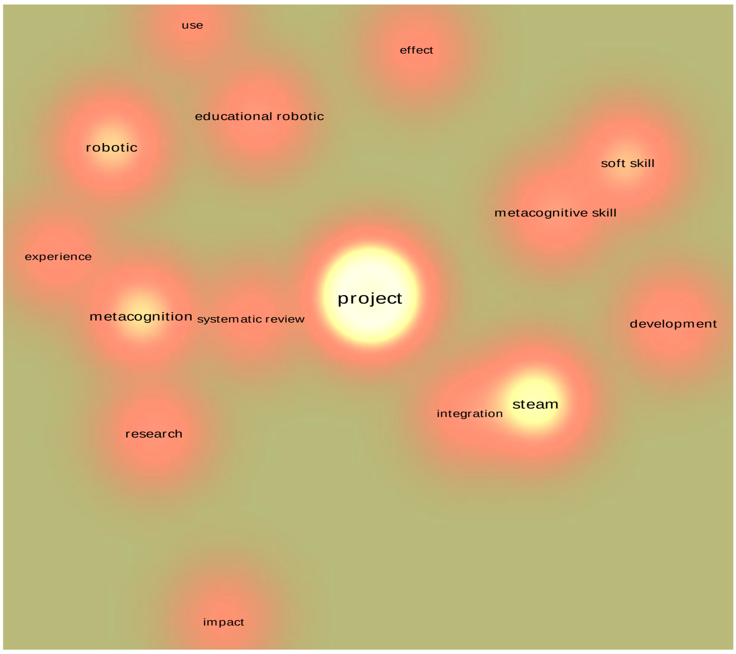


**Fig. 7:** Density visualization VOSviewer

### 3.2. Results of need analysis survey

The survey results presented in Table 1 highlight the lecturers' understanding of the STEAMPjBL concept in Indonesia and Malaysia. The data shows that most lecturers understand this concept to a significant degree, with 66.9% classifying their understanding as very understanding, while 32.3% consider themselves to understand the concept. The proportion of lecturers who gave neutral responses was only 2.4%, which indicates that the general understanding of STEAMPjBL among lecturers in both countries has reached a high level. The very small presence of neutral responses indicates that STEAMPjBL has become an established part of academic consciousness in the lecturer community in Indonesia and Malaysia. These findings confirm that STEAMPjBL has attracted significant interest among lecturers, with a strong belief that this approach can promote interdisciplinary relationships, increase student engagement in the learning process, and incorporate art elements into STEM approaches, which are believed to enrich the student learning experience.

The survey results in Table 1 also reveal that lecturers in Indonesia and Malaysia feel obstacles and challenges in implementing STEAMPjBL. As many as 42.75% of respondents strongly agreed that STEAMPjBL faced obstacles, while 32.8% agreed. Only a small portion gave a neutral response of 13.7%, while 10.5% disagreed and 0.8% strongly disagreed. Further analysis revealed that lecturers considered the need for more financial, technological, and material resources the main obstacle to implementing STEAMPjBL. The significant time requirement in implementing STEAMPjBL was also considered a significant barrier. Another significant challenge is students' readiness and differences in their background knowledge.

Additionally, an analysis of Table 1 reveals a significant need for professional development in the STEAMPjBL context among lecturers in Indonesia and Malaysia. As many as 59.7% of respondents showed high interest in this professional development, while 33.1% expressed their interest. Only a small portion, namely 7.2% of lecturers, gave a neutral response to this need. These findings highlight the urgency of increasing lecturers' competence and understanding of the concepts and practices of STEAMPjBL, which is considered an innovative and relevant educational approach in the contemporary era.

**Table 1:** Percentage of lecturer responses to the need for STEAMPjBL

| Indicators and sub-indicators | Response percentage (%) | | | | |
|---|---|---|---|---|---|
| **Understanding STEAMPjBL** | Strongly agree | Agree | Neutral | Disagree | Strongly disagree |
| STEAMPjBL enhances student engagement | 74.2 | 22.6 | 3.2 | | |
| STEAMPjBL fosters interdisciplinary connections | 77.4 | 22.6 | | | |
| STEAMPjBL promotes critical thinking and problem-solving skills | 54.8 | 45.2 | 3.2 | | |
| Integrating arts in STEM disciplines enriches student learning experiences | 61.3 | 38.7 | 3.2 | | |
| Average | 66.9 | 32.3 | 2.4 | | |
| **Challenges and barriers** | Very significant | Significant | Neutral | Insignificant | Very insignificant |
| Lack of resources (financial, technological, materials) | 48.4 | 25.8 | 19.4 | 6.5 | 3.2 |
| Time constraints (integration into curriculum, class time) | 45.2 | 29 | 16.1 | 9.7 | |
| Assessment and evaluation methods | 35.5 | 37.7 | 9.7 | 16.1 | |
| Student preparedness and background knowledge | 41.9 | 38.7 | 9.7 | 9.7 | |
| Average | 42.75 | 32.8 | 13.7 | 10.5 | 0.8 |
| **Professional development needs** | Very interested | Interested | Neutral | Not interested | Very not interested |
| Workshops/seminars | 64.5 | 29 | 6.5 | | |
| Online courses | 51.6 | 32.3 | 16.1 | | |
| Collaborative projects with other institutions | 61.3 | 38.7 | | | |
| Funding for research and implementation | 61.3 | 32.3 | 6.5 | | |
| Average | 59.7 | 33.1 | 7.2 | | |

The importance of professional development in the STEAMPjBL context is also reflected in lecturers' preferences for certain development methods. Most lecturers preferred workshops or seminars to develop their competencies in STEAMPjBL, with a percentage of 64.5%. Inter-institutional collaboration on research projects is also considered an effective way to improve understanding and practice of STEAMPjBL, with 61.3% of lecturers expressing their interest in this approach.

Table 2 provides an interesting picture of the level of awareness and understanding of students in Indonesia and Malaysia regarding STEAMPjBL. The findings show that as many as 82.6% of students need to become more familiar with the STEAMPjBL concept. In contrast, only 19.4% of them stated that they were familiar with this approach. These data indicate the need for greater efforts to introduce and integrate STEAMPjBL into student learning environments.

Approximately 81% of students believe that integrating STEAM disciplines can enhance their learning experience. This suggests that while not all students are familiar with the STEAMPjBL concept, many recognize its potential benefits for enriching their education. However, 19% of students remained neutral regarding its ability to improve their learning experience through STEAM integration. This emphasizes the importance of adopting an inclusive approach when introducing and implementing STEAMPjBL, as well as the need for greater support from educational institutions and lecturers to help students better understand this concept.

Table 2 provides significant insight into students' views in Indonesia and Malaysia on the importance and relevance of STEAMPjBL. The findings show that most students, as many as 59.3%, agree about the importance and relevance of STEAMPjBL, while 21.9% strongly agree. Only a small portion, namely 20.2%, did not provide a neutral opinion on the importance and relevance of STEAMPjBL. These data highlight students' awareness and understanding of the value and benefits offered by the STEAMPjBL approach in today's higher education context.

**Table 2:** Percentage of student responses to the need for STEAMPjBL

| Indicators and sub-indicators | Response percentage (%) | | | | |
|---|---|---|---|---|---|
| Familiarity about STEAMPjBL | Yes | No | | | |
| I am familiar with the concept of STEAMPjBL | 82.6 | 19.4 | | | |
| **Understanding of STEAMPjBL** | Strongly agree | Agree | Neutral | Disagree | Strongly disagree |
| I understand the benefits of integrating STEAM disciplines in project-based learning | 18.9 | 57.7 | 26.4 | | |
| I believe STEAMPjBL enhances student learning experiences | 31.3 | 58.2 | 11.4 | | |
| Average | 25.1 | 57.9 | 18.9 | | |
| **Perceived importance and relevance** | Very significant | Significant | Neutral | Insignificant | Very insignificant |
| STEAMPjBL is important for preparing students for future careers | 25.4 | 57.2 | 19.4 | | |
| Integrating arts and creativity into STEM disciplines is valuable for holistic learning | 18.9 | 60.2 | 22.4 | | |
| STEAMPjBL promotes interdisciplinary connections and problem-solving skills | 21.4 | 60.7 | 18.9 | | |
| Average | 21.9 | 59.3 | 20.2 | | |
| **Interest in STEAM PjBL opportunities** | Very interested | Interested | Neutral | Not interested | Very not interested |
| In-Class Projects | 17.4 | 53.7 | 29.4 | 0.5 | 0.5 |
| Extracurricular STEAM activities (e.g., clubs, competitions) | 21.4 | 45.8 | 34.3 | 0.5 | |
| Research projects with lecturers and industry partners | 19.4 | 46.3 | 34.8 | | |
| Internships or work experience in STEAM-related fields | 21.9 | 44.3 | 34.3 | 0.5 | |
| Average | 20.0 | 47.5 | 33.1 | 0.3 | 0.1 |

In addition, Table 2 illustrates that most students showed significant interest in STEAMPjBL. As many as 47.5% said they were interested in following this approach, while 20% said they were very interested. Only a small portion, namely 0.4%, is interested in something other than STEAMPjBL. This strong interest reflects the STEAMPjBL approach's great potential in meeting students' needs and expectations in the current educational era. However, it should be acknowledged that many students responded neutrally to STEAMPjBL because they had never used it before, reaching 33.1%. This highlights the importance of a systematic and targeted approach in introducing and implementing STEAMPjBL among university students. Thus, there is an opportunity to increase their understanding and awareness of the potential and benefits of STEAMPjBL through a planned and measurable approach.

Further analysis of Table 2 reveals students' preferences for implementing STEAMPjBL. Many students, approximately 71.1%, expressed their interest in using STEAMPjBL through STEAM Projects in class, while 67.2% were interested in extracurricular activities. This shows that students want practical and actively involved learning experiences, which they can find through the STEAMPjBL approach. Thus, the development of STEAMPjBL to nurture soft skills and metacognition awareness is needed from a systemic literature review and survey perspective.

## 4. Discussion

### 4.1. STEAM research potential

Based on the clusters resulting from data analysis using VOSviewer, research potential in three areas can be identified, namely (1) Development of STEAM skills in an educational context, (2) Use of robotic education to improve learning experiences, and (3) Evaluation of systemic effects and impacts. These studies offer valuable contributions to understanding how education can be adapted to strengthen STEAM skills, enrich learning experiences through integrating robotic technology, and evaluate the systemic impact of such educational initiatives. A research focus on these three areas can expand the scope of knowledge in education and technology and provide a strong basis for developing more effective educational policies and practices.

In-depth research in developing STEAM skills in an educational context can be carried out to design an integrated curriculum with the STEAM approach, which emphasizes mastery of academic material and developing students' soft and metacognitive skills. This kind of curriculum development takes a holistic approach, considering various aspects of learning, such as material content, teaching methods, and assessment of learning outcomes. The STEAM approach involves the integration of Science, Technology, Engineering, Arts, and Mathematics, allowing students to obtain meaningful and relevant learning experiences that address the complexities of the modern world (Ding et al., 2022). By incorporating interdisciplinary elements, STEAM education fosters comprehensive talents with innovative qualities, improves education quality, and enhances teaching effectiveness. It also promotes applying knowledge from different fields, encourages project-based learning, and supports the development of problem-solving abilities and self-regulated learning. To design an effective STEAM curriculum, it is important to consider the interaction and synergy among the different STEAM elements, ensuring that students receive a well-rounded and relevant education.

Educational robotics increases student engagement in learning and allows the development of metacognitive skills that are important for continuous learning. Research highlights the importance of understanding how educational robotics can influence students' learning experiences and how metacognitive skills can be enhanced through interaction with this technology. Research can be conducted to develop and test robotic learning models that integrate aspects of metacognition, practical experience, and scientific research to improve students' understanding of technical concepts and soft skills. Robots in education can enhance the development of metacognitive abilities (Adnan et al., 2023). Additionally, integrating computational thinking (CT) and adversarial thinking (AT) into robotics learning can improve educational methods and critical thinking skills (Özkan and Toz, 2022). Educational robotics (ER) can be a pedagogical tool to attract students to problem-solving activities and develop cognitive and soft skills (Scaradozzi et al., 2021). Students can enhance their problem-solving abilities by integrating CT into ER and nurturing computational thinking skills (Verónica and Rodríguez Muñoz, 2023). Furthermore, the application of educational robotics in teaching practice has been shown to improve conceptual achievement and the application of transversal competencies such as problem-solving and critical thinking (Ahmadaliev et al., 2022). Therefore, research integrating metacognition, practical experience, and scientific research into robotic learning models can improve students' understanding of technical concepts and soft skills.

Evaluate the effects and impacts of various interventions or innovations in educational contexts. Research in this cluster often involves systemic analysis to understand how changes in one area can affect the system. Systemic reviews provide an in-depth understanding of the effects and impact of various educational strategies, assisting in developing policies and best practices. Systemic reviews in educational research, particularly in Educational Technology, have increased. These reviews aim to synthesize and accumulate the results of different primary studies, identify research gaps, and guide future work. The impact of various educational innovations on the education system is a key focus of these reviews. They evaluate the effects and impacts of innovative teaching practices, such as problem-based learning, blended learning, gamification, and flipped learning, on student learning outcomes and academic achievement. The reviews also highlight the importance of teacher training and continuous professional development in implementing these innovative approaches effectively. By conducting a comprehensive analysis, these systemic reviews contribute to improving education quality by identifying educational systems' strengths and weaknesses from a systemic perspective (Aparicio et al., 2021). Further research is needed to evaluate these approaches' long-term impact and sustainability in improving student outcomes (Mejía-Rodríguez and Kyriakides, 2022). By paying attention to these clusters, education research can be focused on answering important questions regarding the development of student skills, the application of technology in learning, and evaluating the effects of educational innovations at the individual and system levels.

Research on the long-term impact of STEAM learning programs can provide insights into the skills, knowledge, and competencies acquired by students, schools, and society. Studies have shown that STEAM learning in elementary schools can improve the quality of education and help develop 21st-century skills. Applying STEAM in physics education has been found to enhance students' problem-solving, critical thinking skills, and understanding of concepts (Amiruddin et al., 2022). Furthermore, using STEAM in mathematics education has been associated with improved problem-solving skills and creativity. However, the impact on collaborative and communication skills still needs to be improved (Pahmi et al., 2022). The coordinated use of STEAM has been found to enhance linguistic and mathematical competencies, particularly in speaking, oral comprehension, and calculation (Duo-Terron et al., 2022). Overall, research on STEAM learning programs can provide valuable insights into the long-term effects on students' skills and knowledge acquisition, highlighting the importance of integrating STEAM into education.

### 4.2. The need for developing the STEAMPjBL model

The survey results indicated a strong understanding of STEAM Project-Based Learning (STEAMPJBL) among lecturers, highlighting its significant global development potential. The results of this survey provide a strong foundation for advocacy and further development of STEAMPJBL in the context of global higher education. This model is not only recognized as relevant but also as a crucial tool in addressing the demands of contemporary education. STEAMPJBL integrates science, technology, engineering, arts, and mathematics, fostering 21st-century skills such as critical thinking, creativity, and communication. By implementing

STEAMPJBL, students engage in hands-on learning experiences, applying their knowledge across various disciplines, thus enhancing their competencies to meet the challenges of the 21st century (Kautsar, 2023). This approach enhances students' soft skills like communication and collaboration and promotes technological literacy, making learning interactive and effective.

The lecturers' survey results also show the evident challenges and barriers to adopting STEAM-PjBL in higher education, particularly in the context of developing countries. Educators need more technology resources, better internet connectivity, more professional development, and a lack of incentives (Meng et al., 2023). Additionally, STEAM-integrated Project-Based Learning has been shown to foster 21st-century skills but requires significant investment in resources and support (Caton, 2021). Greater efforts are needed to overcome time challenges and develop efficient strategies for integrating STEAMPJBL into existing curricula. Other challenges, such as student preparedness, demonstrate the need for a diverse and inclusive approach to ensure that all students can access and benefit from this approach, regardless of their background. With a deep understanding of these barriers and challenges, a holistic and integrated approach can be developed to ensure the successful implementation of STEAMPJBL in higher education contexts in Indonesia, Malaysia, and worldwide.

Further analysis of the survey results of lecturers shows that professional development efforts in the STEAMPjBL context are considered not only individual needs but also an opportunity to expand collaborative networks between lecturers and institutions. The results of this survey provide a strong basis for directing appropriate professional development efforts to support the adoption and implementation of STEAMPjBL at the higher education level. Research emphasizes the importance of preparing teachers for project-based learning (PJBL) activities, highlighting the need for methodological knowledge, language skills, and ICT practice to effectively integrate innovative techniques into teaching. Furthermore, integrating STEAM into classrooms through professional development enhances creativity and social skills, contributing to sustainable educational practices and increasing student motivation (Conradty and Bogner, 2020).

The survey results showed that most students needed to become more familiar with STEAMPjBL, and a few gave a neutral opinion on its importance and relevance. This may indicate differences in their understanding or experience of these concepts and variations in learning approach preferences among students. Thus, there needs to be continued efforts to provide broader and in-depth information about the value and benefits of STEAMPjBL to students and create a learning environment that supports and facilitates the adoption of STEAMPjBL. By providing engaging and interactive learning experiences, STEAM-PjBL fosters enthusiasm and satisfaction in learning and encourages active student participation and understanding of complex scientific concepts (Shatunova et al., 2019). Creating a supportive learning environment that embraces STEAM-PjBL methodologies can significantly benefit students by preparing them for the demands of the modern era.

The survey results also showed that students were interested in using STEAMPjBL through the STEAM Project in class and extracurricular activities. The results of this survey provide a basis for developing more effective educational strategies in introducing and integrating STEAMPjBL into the learning model. With the integration of STEAMPjBL in the learning model, students can develop a broader understanding of various disciplines, including programming, mechanics, electronics, and design (Hu et al., 2023). Through this project, students can also learn to collaborate in teams, solve complex problems, and develop their creativity in designing and building innovative solutions (Drakatos and Stompou, 2023).

Several recent studies have been conducted regarding the needs analysis of STEAM project-based learning, namely an analysis of domestic research trends in art-based STEAM education (Lee and Lee, 2017). Needs analysis of natural science learning media development with STEAM-Based Augmented Reality (Rukayah et al., 2021). The needs analysis of Project-Based Learning model development in translation as a professional course. Need analysis of technology-based project-based learning in higher education (Anugraha and Padmadewi, 2022). A Need Analysis of English Hybrid Learning Using Open Broadcaster Software through Project-Based Learning (PJBL) Model (Pandesha et al., 2023). The Needs Analysis for Developing an Ethnoecological-STEAM Project-Based Learning. The few studies that have been carried out have yet to examine the analysis of the need for developing STEAM Project-based Learning to increase soft skills and metacognition awareness. Besides that, previous research has yet to use a method to conduct needs analysis research.

This research was carried out by combining a method of systemic literature review, qualitative research using VOSviewer to obtain research potential in the STEAM Project-Based Learning area, and quantitative research using surveys to analyze the need for developing STEAM Project-Based Learning among lecturers and students. Combining these two methods makes the analysis of needs for the development of STEAM Project-Based Learning in this research more comprehensive. Thus, this research is relevant and has contributed to building body knowledge in STEAMPjBL research.

Further research into the development of STEAM projects in robotic learning can significantly contribute to the understanding of how innovative educational approaches can improve students' soft and metacognitive skills. This can pave the way for developing more effective and relevant learning strategies in future education. This STEAM project provides practical knowledge about robotics and helps form skills and competencies that are important to face challenges in an era of ever-evolving technology (Farooq et al., 2023). Within the project-based learning framework, students engage in iterative cycles of planning, implementation, and reflection, enhancing their awareness and control over cognitive processes (Deshpande, 2022). Through self-monitoring, students develop the ability to analyze their thought patterns, identify strengths and weaknesses, and make informed adjustments to optimize their learning experiences (Zarouk, 2023). Reflection serves as a mechanism for consolidating learning as students critically evaluate their approaches, identify successful strategies, and identify areas for improvement. Engagement in STEAM projects also requires cultivating effective self-regulation skills as students navigate project management complexities, allocate resources wisely, and sustain motivation in the face of challenges.

### 4.3. The practical implementation and potential challenges of STEAMPjBL

The practical implementation of the STEAMPjBL learning model, which is oriented to fostering soft skills and metacognitive awareness, is as follows.

#### 4.3.1. Preparation stage

The preparation stage aims to set goals, initial understanding, and project preparation. Activities carried out at this preparation stage include: (a) Selecting a project topic relevant to STEAM. (b) Determine learning objectives by targeted learning outcomes. (c) Create interesting and challenging trigger questions. (d) Form heterogeneous working groups to increase collaboration and exchange of ideas. (e) Provide questions that reflect the initial knowledge students need to complete the project.

#### 4.3.2. Project planning stage

The project planning stage aims to plan and design the project in detail. Activities carried out at this stage include: (a) Each group discusses to generate ideas about how to achieve the project goals. (b) Determine the roles and responsibilities of team members based on their skills and interests. (c) Identify required resources, including tools, materials, and information. (d) Create a project plan that includes the steps and schedule for project completion.

#### 4.3.3. Project implementation stage

The project implementation phase aims to implement the project plan and develop the product. Activities at this stage include: (a) Each group begins to design and develop a fruit harvesting robot, integrating concepts from various STEAM disciplines. (b) Testing robot prototypes and making modifications based on test results. Students apply critical thinking and problem-solving skills to overcome obstacles that arise.

#### 4.3.4. Project progress monitoring stage

The project progress monitoring stage aims to monitor and reflect on the learning process. Activities at this stage include (a) Holding periodic checkpoints where groups report project progress and receive feedback from educators and peers. (b) Each group reflects on their work process, including the challenges faced and problem-solving strategies used. (c) Document the project development process through journals, photos, videos, or reports.

#### 4.3.5. Presentation and evaluation stage

The presentation and evaluation stages aim to showcase project results and evaluate processes and products. Activities at this stage include (a) Each group presents the results of their project in front of the class. (b) Each group demonstrates a fruit harvesting robot and how it works. (c) Carry out project evaluations through peer and educator assessments based on predetermined criteria, such as innovation, effectiveness, and integration of the STEAM concept. (d) Students reflect on what they learned from the project they created and how they can apply this knowledge and skills in the future.

Although STEAMPjBL has many advantages, it also has potential challenges in practical implementation. Some potential challenges in STEAMPjBL practice include: (a) Lack of access to tools and materials needed for the project can hinder the implementation of STEAMPjBL. (b) Harmonizing knowledge from different disciplines into one integrated project can be a challenge. (c) Completing the project within the specified time limit requires good time management from students and teachers. (d) Manage differences in student ability levels within a team to ensure balanced contributions. (e) Develop holistic and fair assessment methods to measure project success. (d) Provide constructive feedback to students to support continued learning.

## 5. Conclusion

Based on the cluster analysis and discussion above, there is great potential in developing STEAM Project-Based Learning to improve students' soft and metacognitive skills. Further research and practical implementation of the STEAM Project developments in robotic learning have great potential to enrich existing educational approaches, providing significant benefits for students in developing the skills necessary for success in this modern era. The survey results of lecturers provide a strong foundation for advocacy and further development of STEAMPJBL in the global higher education context. Professional development efforts in the STEAMPjBL context are considered not only individual needs but also an opportunity to expand collaborative networks between lecturers and institutions. The survey results showed that most students needed to become more familiar with STEAMPjBL but were interested in using STEAMPjBL through the STEAM Project in class and extracurricular activities.

## 6. Limitations

This research focuses only on cluster analysis and opinion surveys without providing details about practical implementation or real experiments of STEAM project-based learning. Although there is great potential in developing STEAM project-based learning to improve students' soft skills and metacognition awareness, this research has yet to explore potential challenges or obstacles in its implementation, such as resource needs, teacher training, or curriculum changes. Further, more comprehensive and experimental research can be conducted to strengthen the findings and facilitate the effective implementation of STEAM project-based learning in various educational contexts.

## 7. Recommendations

The recommendations based on this research are as follows: (1) Develop and implement STEAM project-based learning in educational settings to enhance students' soft skills and metacognitive awareness, which are essential in today's modern world. (2) Conduct further studies focused on incorporating STEAM projects in robotics education to enrich current teaching methods and equip students with valuable skills for future success. (3) Promote and advocate for the adoption of STEAMPjBL in global higher education, as survey results indicate strong support from lecturers for its continued development. (4) Raise awareness and increase familiarity with STEAM project-based learning among students, as survey findings show that while many students are unfamiliar with this approach, they express interest in engaging with it both in classrooms and through extracurricular activities.

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## Compliance with ethical standards

## Ethical considerations

Informed consent was obtained, participation was voluntary, and data confidentiality was maintained throughout the study.

## Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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