



Integrasi Machine Learning Dalam Sistem Adaptive Learning Untuk Siswa Berkebutuhan Khusus: Analisis Bibliometrik Literatur Ilmiah

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Abstract: The advancement of artificial intelligence technology, particularly machine learning, has driven transformation in adaptive learning systems, especially for students with special needs. This study aims to analyze global research trends and mapping related to the integration of machine learning in adaptive learning for inclusive education. The method used is bibliometric analysis using the VOSviewer tool. Data were collected from Google Scholar using the Publish or Perish application with the keywords “machine learning”, “adaptive learning”, “special needs”, “education”, and “student” within the range of 2019–2024. The results show relevant publications with a significant increasing trend since 2022. The bibliometric mapping visualization generated 43 key terms grouped into 5 major clusters. The main cluster that emerges as the dominant focus in the research is the adaptive systems and technology cluster, which encompasses the development of learning platforms based on machine learning to support personalization and enhance the effectiveness of learning for students with special needs. These findings highlight the growing academic attention in this field and provide direction for researchers and educational technology developers.

Keywords: adaptive learning, education, machine learning, special needs, student.

INTRODUCTION

Adaptive learning is an educational approach designed to adjust teaching materials and methods based on the individual needs of students (Abdulmajid, 2020). In the context of inclusive education, this approach plays an important role because it is able to provide more personalized learning, especially for students with special needs who have very diverse learning profiles. The use of artificial intelligence technology, especially machine learning, has encouraged

the development of more sophisticated adaptive learning systems (Das et al., 2024). Through data analysis and patterns of student learning interactions, machine learning can predict learning needs more accurately and provide recommendations for appropriate teaching materials and strategies.

Along with the increasing attention to inclusive and technology-based education, studies on the integration of machine learning in adaptive learning continue to grow (Maulidin, 2024). However, the research map on this topic is still scattered and does not yet show a systematic structure. Several studies have discussed the effectiveness of adaptive learning models with AI support, but not many have specifically examined global research trends in the context of students with special needs. This indicates a need for more in-depth and structured studies to understand the scientific landscape and the direction of research development in this field.

This study aims to fill this gap by conducting a bibliometric analysis of scientific publications related to the integration of machine learning in adaptive learning for students with special needs. Through this method, the study can identify publication trends, thematic clusters, influential authors and institutions, as well as potential directions for future research. This study is novel in its systematic and comprehensive mapping of the literature, which has not been widely done in the context of artificial intelligence-based adaptive education for students with special needs. The results of this study are expected to contribute theoretically and practically to the development of learning systems that are more inclusive and responsive to the needs of all students.

Artificial intelligence has become one of the technological breakthroughs that has had a major impact in various fields, including education. The presence of AI offers great potential in supporting the learning process of children with special needs in schools that provide inclusive education. Inclusive schools are educational institutions that provide services to all students, both regular students and students with special needs, in an equal learning environment and system (Pratama, F. I. P., & Husadani, R., 2025).

AI capabilities that resemble human intelligence open up opportunities to create learning processes that are more flexible, adaptive, and tailored to the needs of each individual. Children with special needs generally have physical, behavioral, emotional, or intellectual conditions that differ from those of typical children, including the possibility of above-average potential. These conditions require a special approach that includes educational services, therapy, medical assistance, and family support.

The obstacles experienced by children with special needs can affect their understanding of the subject matter, cause communication limitations, and create difficulties in adjusting to the learning styles commonly used in the classroom (Pratama, F. I. P., & Husadani, R., 2025). Inappropriate handling can hinder their potential development. Therefore, schools need to play an active role as facilitators in creating a supportive and friendly learning environment for special needs.

The application of AI in this context is a promising solution. This technology is capable of providing learning materials tailored to students' abilities, offering digital tools, and conducting automatic assessments to monitor student progress in real time. The learning environment becomes more personalized, interactive, and responsive thanks to systems developed through AI (Vivian Nikadinata, Wahyu Amirul Ikhsan & Beny Dwi Lukitoaji., 2025).

AI-based technology also supports accessibility for students with disabilities through features such as text-to-speech, voice recognition, and simplification of visual and audio content. This utilization is able to accommodate various learning styles and student needs more evenly (Hermanto, S.Pd., M.Hum., 2023). Data analysis conducted by AI systems is also useful in identifying gaps in the learning process and outcomes, enabling schools to take immediate action as needed.

The use of AI in inclusive education shows a new direction in realizing an education system that is fair, equitable, and centered on the needs of each student. This study was conducted to systematically review various literature discussing the application of AI in supporting education for children with special needs in inclusive schools (Andriana, a., 2025).

METHOD

This study uses a bibliometric analysis approach to map the trends, distribution, and patterns of scientific publications discussing the integration of machine learning in adaptive learning systems for students with special needs. Bibliometric analysis was chosen because it can provide a quantitative overview of the development of research topics based on publication data from reputable scientific databases. The stages of the method are as follows:

Tools and materials

This study used a Systematic Literature Review (SLR) approach with the help of software that supports the process of searching, managing, and analyzing scientific library data. The literature search process was conducted using the Publish or Perish version 8.2 application, which was operated on an ASUS VivoBook M413DA laptop with an AMD Ryzen 5 3500U processor, 8 GB RAM, and Windows 11 operating system. The references obtained were managed using Mendeley Reference Manager version 2.93.0 to store, group, and annotate each article.

The Research Process

This research was conducted systematically using the Systematic Literature Review method, which consists of several stages. Each step was designed so that it could be replicated by other researchers with similar results, as long as they used the same approach and tools.

1. Step I Formulating the Focus and Research Questions

The first step began with formulating the main focus of the research, namely how artificial intelligence (AI) is used to support the learning

process of children with special needs in inclusive schools. From this focus, research questions were formulated to serve as the basis for literature search and selection.

2. Step II Literature Search

The literature search was conducted using the Publish or Perish application, by accessing the Google Scholar database. The keywords used included: "Artificial Intelligence in Inclusive Education," "AI for Special Needs Students," and "AI and Learning Disabilities." The search focused on articles published between 2015 and 2025 to ensure that the information obtained was still relevant and up to date.

3. Step III Article Selection and Screening

Articles obtained from the search results were then selected using inclusion and exclusion criteria. The inclusion criteria included scientific articles that discussed the use of AI in special needs education and were available in full-text form. Meanwhile, articles that were non-scientific, irrelevant, or duplicates were eliminated. The screening process is carried out by reading the title and abstract, followed by reading the full content of articles that pass the initial stage.

4. Step IV Reference Management

Articles that meet the criteria are entered into the Mendeley Reference Manager application to facilitate the management, grouping, and tagging of citations. Each article is annotated and tagged based on the main themes found, such as the type of AI technology used, teaching methods, and the specific needs groups targeted by the research.

5. Step V Thematic Analysis and Data Visualization

The collected articles were analyzed using a thematic synthesis approach. Themes that emerged from the content of the articles were identified and grouped based on similarities in focus and findings. To strengthen the analysis, bibliometric data visualization was also performed using the VOSviewer application. This application helps to see the relationships between keywords, frequently discussed topic trends, and collaboration networks between authors.

6. Step VI Compilation of Results and Data Interpretation

After the analysis process was complete, the research results were compiled in the form of a narrative that presented a thematic synthesis of the various articles. Each finding is compared and linked to one another to obtain a comprehensive picture of how AI plays a role in inclusive education. This process also involves critical reflection on trends, gaps, and the direction of further research development.

Data analysis

Data analysis in this study was conducted through two approaches, namely thematic analysis to compile a synthesis of article content, and bibliometric analysis to visually examine the relationship between terms and research trends.

Articles that passed the selection process were analyzed using a thematic synthesis approach. This process was carried out by reading the content of the articles in depth to find the main themes related to the use of artificial intelligence (AI) in inclusive education. Themes that emerged, such as the types of AI used, forms of support for students with special needs, and the impact on the learning process, were recorded and grouped. The results of this grouping were used to compile a narrative synthesis that describes the trends in previous research content.

Bibliometric analysis uses bibliographic data collected from previous articles imported into VOSviewer in CSV or RIS format. VOSviewer then processes keywords that frequently appear in titles and abstracts. From this data, the frequency of keyword occurrence (cooccurrence) and the strength of their relationship in the visual map are calculated.

VOSviewer uses the principle of association strength, which is expressed in the following formula:

$$S_{ij} = \frac{C_{ij}}{W_i \times W_j}$$

Explanation:

S_{ij} = strength of association between keywords i and j

c_{ij} = number of co-occurrences between i and j in the document

w_i = total number of occurrences of word i

w_j = total number of occurrences of word j

The higher the S_{ij} value, the stronger the relationship between the two words in the context of the analyzed document. The results of this formula are used by VOSviewer to group keywords into clusters or thematic groups. Each cluster shows the dominant focus of discussion, for example, the AI and curriculum adaptation group, AI and student social skills, or AI and technology accessibility. The resulting visual map also shows different sizes and colors for each keyword. The size reflects frequency, while the color indicates the proximity or similarity of context between words. This map helps researchers see trends, research gaps, and the most frequently studied thematic focuses in the context of AI and inclusive education.

The results of this analysis form the basis for the discussion, while also reinforcing the conclusion that the integration of AI in inclusive education is not only possible, but is also developing in a direction that is more adaptive to the needs of children with special needs.

RESULT AND DISCUSSION

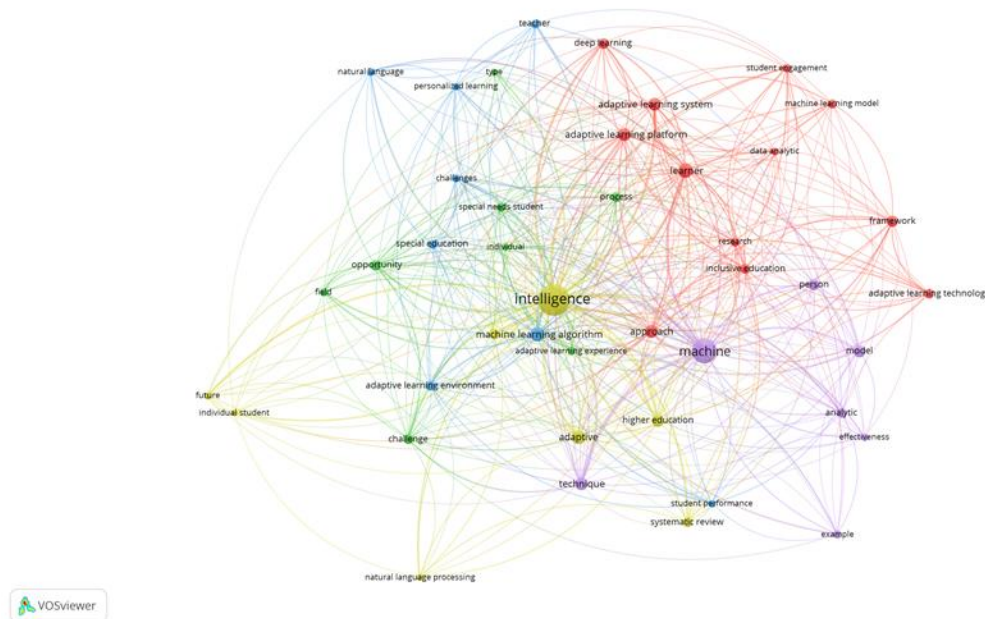
Based on data analyzed using VOSviewer, the trend of scientific publications related to the integration of machine learning in adaptive learning systems for students with special needs shows rapid development in recent years. The number of publications began to increase significantly since 2022 and peaked in 2023 and 2024, as indicated by the number of keywords and authors with an average publication score above 2023. There were 500 publications found

in the 2019-2024 range. The results of the bibliometric analysis of 43 terms identified through VOSviewer show that research on machine learning in adaptive learning for students with special needs has increased significantly in the last three years. Most terms have an average publication year above 2023, indicating that this topic is very current and continues to evolve.

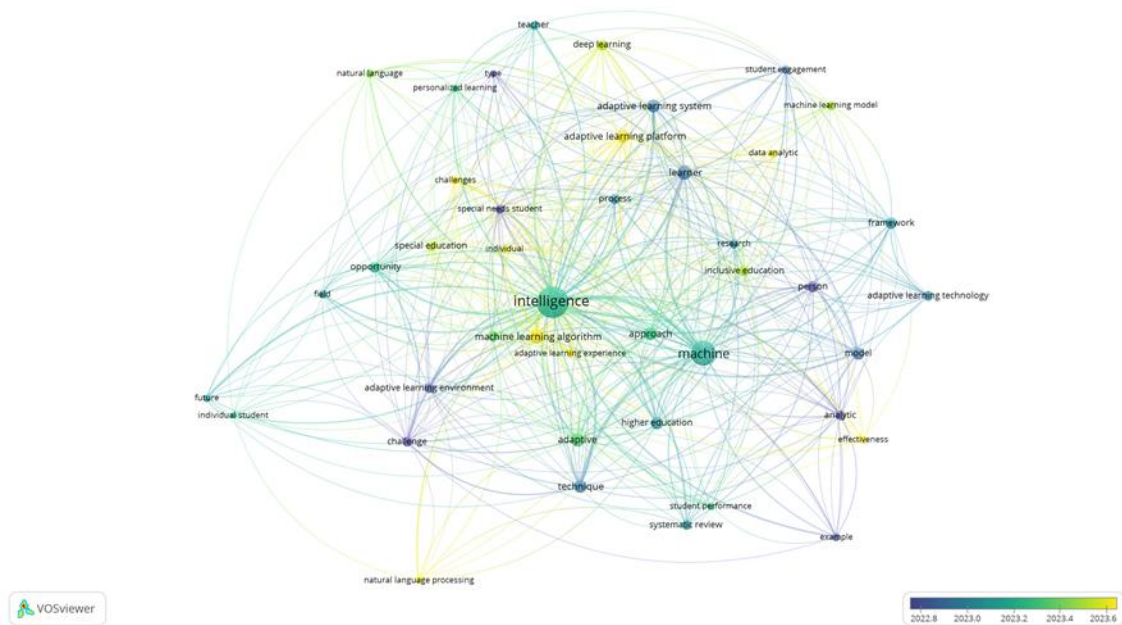
Visualization of the topic area of machine learning integration in adaptive learning systems for students with special needs using VOSviewer based on the collected articles shows that there are 43 related items divided into 5 clusters, namely:

- i. Cluster 1, marked in red, has 12 items, including adaptive learning platform, adaptive learning system, adaptive learning technology, approach, data analytics, deep learning, framework, inclusive education, learner, machine learning model, research, and student engagement.
- ii. Cluster 2, marked in green, has 8 items, including adaptive learning experience, field, individual, opportunity, process, special needs student, and type.
- iii. Cluster 3, marked in blue, has 8 items, including adaptive learning environment, challenges, machine learning algorithm, natural language, personalized learning, special education, student performance, and teacher.
- iv. Cluster 4, marked in yellow, has 8 items, including adaptive, future, higher education, individual student, intelligence, natural language processing, special needs education, systematic review.

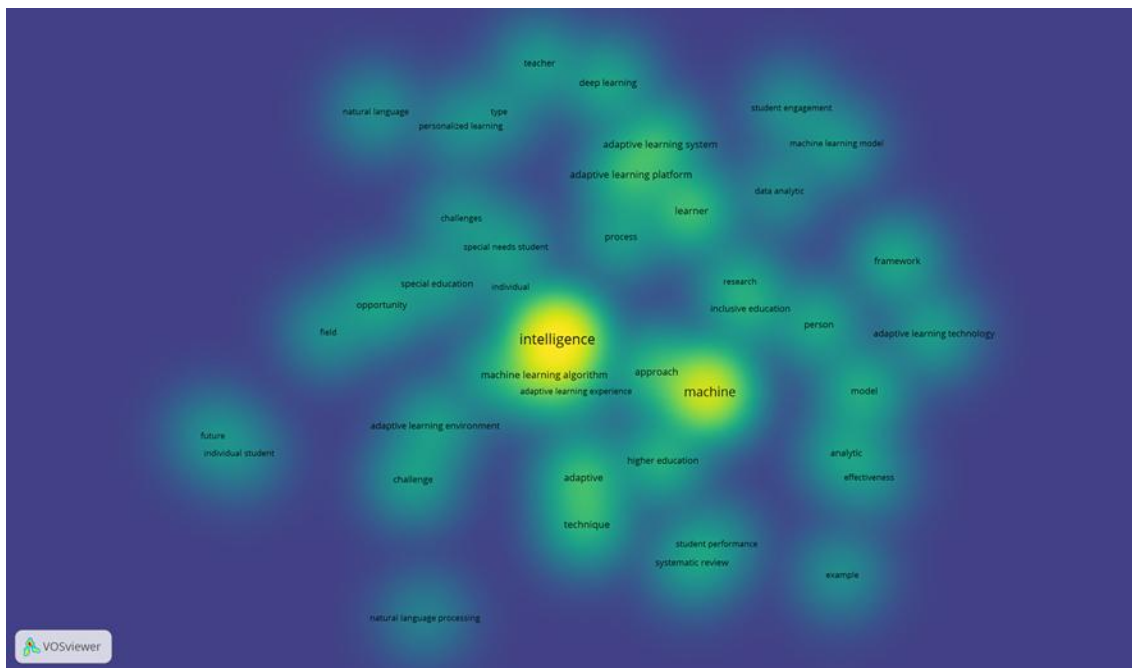
Cluster 5, marked in purple, has 7 items, including analytic, effectiveness, example, machine, model, person, technique.



Gambar 1. Network Visualization



Gambar 2. Overlay Visualization



Gambar 3. Density Visualization

The mapping results shown in Figure 1 and Figure 3 indicate that terms with high occurrence and link strength are spread across five clusters, with clusters 1 and 4 occupying the dominant portion. Cluster 1 contains terms such as adaptive learning platform, framework, learner, and inclusive education, which describe a focus on the development of technology-based inclusive learning systems and approaches. Meanwhile, cluster 4 includes terms such as adaptive, special needs education, higher education, and intelligence. This

cluster indicates a focus on the application of artificial intelligence in supporting the learning of students with special needs in higher education and inclusive environments. The dominant focus of all clusters shows that the main topic that continues to develop is the development of machine learning-based adaptive platforms to support personalization and learning effectiveness (Rachman, 2025). This can be seen from the high occurrence values of terms such as adaptive (33), learner (37), machine learning algorithm (38), and intelligence (176).

Figure 2 shows that from 2022 to 2024, there has been a shift in research focus from general concepts of machines and intelligence towards practical implementations such as adaptive learning platforms, deep learning, and machine learning algorithms to support adaptive and inclusive learning systems.

CONCLUSION

This study shows that the integration of machine learning in adaptive learning systems for students with special needs has undergone significant development in recent years, especially since 2022. Bibliometric analysis reveals five main clusters that reflect the focus of research, such as the development of adaptive learning platforms, personalization of materials, and improved accessibility for students with special needs. These findings confirm that artificial intelligence-based technology, particularly machine learning, plays an important role in creating an education system that is more inclusive and responsive to individual needs.

There is great potential for machine learning to support learning effectiveness through real-time data analysis and tailored material recommendations. However, further research is needed to address implementation challenges, such as the availability of representative data and collaboration between technology developers and educators. Thus, the integration of machine learning in adaptive learning not only promises innovative solutions but also opens up new opportunities for the development of inclusive education in the future.

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