Optimizing Teacher Training and Retraining for the Age of AI-Powered Personalized Learning: A Bibliometric Analysis

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Abstract. The rapid advancement of artificial intelligence (AI) technologies has ushered in transformative changes in education, with AI-powered personalized learning systems emerging as a game-changing innovation. However, the successful implementation of these intelligent systems hinges on the preparedness and competence of educators to effectively harness their potential. This bibliometric analysis provides a comprehensive exploration of the research landscape on teacher training and retraining for AI-powered personalized learning. By analyzing publications, authors, institutions, countries, sources, and keyword co-occurrences, this study unveils key insights, trends, and potential gaps. The results highlight the recent surge in research interest, driven by practical AI applications and the COVID-19 pandemic's impact on education. Influential contributors, institutions, and countries are identified, shedding light on the geographical distribution and collaborative networks shaping this field. The analysis reveals the multidisciplinary nature of the research, with contributions from diverse domains such as educational technology, artificial intelligence, sustainability, and wireless communications. Through keyword co-occurrence analysis, prevalent themes, concepts, and emerging trends are uncovered, including the central focus on teachers, technology, teaching practices, classroom environments, curriculum, and specific AI models like ChatGPT. While the study identifies potential research gaps, such as the need for more pedagogical implications of AI in education, the insights gained can assist in development of effective teacher training and retraining programs, equipping educators to navigate the transformative age of AI-powered personalized learning.

Keywords: Teacher Training · Professional Development · Artificial Intelligence · Large Language Models · Personalized Learning · Adaptive Learning · Education Technology · Bibliometric Analysis · Research Trends

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1 Introduction

The rapid advancement of artificial intelligence (AI) technologies has ushered in a transformative era in education. AI-powered personalized learning systems have emerged as a game-changing innovation, promising to revolutionize how we approach teaching and learning [8]. These intelligent systems leverage machine learning algorithms and vast amounts of data to tailor educational experiences to the unique needs, preferences, and learning styles of individual students [17]. By adapting content, pace and instructional methods dynamically, personalized learning aims to create a more engaging, effective, and student-centred educational experience.

The potential benefits of AI-powered personalized learning are manifold. First, these systems can address students' diverse learning requirements, catering to their varying abilities, backgrounds, and interests. By providing personalized content and support, these intelligent systems can help students overcome barriers to learning, fostering a more inclusive and equitable educational environment [11]. Additionally, personalized learning can enhance student motivation and engagement, as learners are presented with content and activities tailored to their unique preferences and goals [6].

Furthermore, AI-powered personalized learning systems can provide educators with valuable insights and data-driven recommendations, enabling them to make informed decisions about instructional strategies and interventions [16]. By analyzing student performance data and learning patterns, these systems can identify areas of strength and weakness, facilitating targeted support and remediation efforts. This data-driven approach can potentially improve student outcomes and optimize the learning process.

However, the successful implementation and sustained impact of AI-powered personalized learning hinge on a critical factor: the preparedness and competence of educators themselves. As these innovative technologies continue to permeate the educational landscape, teachers and instructors must adapt their pedagogical approaches and develop new skills to harness the potential of these tools effectively. Failure to adequately equip educators with the necessary knowledge and competencies could lead to suboptimal utilization of these powerful technologies, hindering their transformative impact on student learning and achievement.

Recognizing the pivotal role of teachers in this technological revolution, the need for comprehensive teacher training and retraining programs has become increasingly paramount. Educators must have a deep understanding of AI-powered personalized learning systems, including their underlying algorithms, data analysis techniques, and ethical considerations. Additionally, they must develop proficiency in integrating these technologies into their teaching practices, adapting their instructional strategies to leverage the personalized learning experience effectively.

Moreover, teacher training and retraining efforts must go beyond mere technical proficiency. Educators must also cultivate a growth mindset and embrace a culture of continuous learning, as the field of AI and personalized learning is rapidly evolving. They must be prepared to adapt to new technologies, collaborate with interdisciplinary teams, and engage in ongoing professional development to remain at the forefront of this transformative educational paradigm.

This bibliometric analysis aims to provide a comprehensive examination of the existing literature on teacher training and retraining in the context of AI-powered personalized learning. By systematically analyzing and mapping the research landscape, this study seeks to identify the current trends, influential works, and potential gaps in this rapidly evolving field. Through a rigorous bibliometric approach, we will explore the following key research questions:

1. What are the prominent themes and research hotspots in the literature on teacher training and retraining for AI-powered personalized learning?
2. Which authors, institutions, and countries are leading the research efforts in this area?
3. What are the most influential and highly cited publications shaping the discourse on this topic?
4. How has the research landscape evolved, and what future directions can be discerned from the bibliometric analysis?

By addressing these research questions, this study aims to provide a comprehensive understanding of the current state of research and identify potential avenues for future exploration. The insights gained from this bibliometric analysis will inform the development of effective teacher training and retraining programs, ensuring that educators are adequately prepared to navigate the age of AI-powered personalized learning.

2 Methodology

The primary methodology employed in this study was a bibliometric analysis of research trends related to teacher training and retraining for AI-powered personalized learning environments. The analysis focused on research articles published between 2010 and 2023, as the integration of AI in education gained significant traction during this period.

2.1 Search Database and Strategy

This study was conducted using a scientific database known as Dimensions. Table 1 compares Dimensions, Scopus, and Web of Science, according to which the Dimensions database is the most appropriate for bibliometric analysis regarding coverage. This digital platform includes citation data, research analytics features, and scholarly e-content. The consideration of the Dimensions database was based on its ability to link and offer rich contextual search and data visualisation of huge amounts of data, which include the number of citations per publication. The Dimensions database constitutes the overall research landscape. It helps to bring a broader context of research, the researcher, a research field, an institution, a country, and many other major research issues that may interest stakeholders in the research world [12].

2.2 Literature Search Strategy

The literature search used a combination of relevant keywords, including “teacher training”, “professional development”, “artificial intelligence”, “personalized learning”, “adaptive learning”, and related terms. The search was limited to documents published in English between 2010 and 2023.

Table 1. Comparison of Dimensions, Scopus and Web of Science for bibliometric analysis.

Characteristics	Dimensions [1]	Scopus [2]	Web of Science [3]
Publisher	Digital Science	Elsevier	Clarivate Analytics
Publication coverage	More than 143 million records from patents, research papers, clinical trials, etc.	More than 82 million records from scientific journals, books and conferences	More than 79 million records from scientific journals, books, conference proceedings and patents
Chronological coverage	From 1665 to the present	From 1788 to the present	From 1900 to the present
Subject areas	All branches of science	All branches of science	All branches of science
Types of publications	Journal articles, books, patents, preprints, clinical trials, etc.	Journal articles, books, conference proceedings	Journal articles, books, conference proceedings, patents
Indexing	Hybrid model with expert selection and machine text analysis	Expert selection of sources with a formal evaluation process	Expert selection of sources with a formal evaluation process
Analysis tools	Powerful tools for bibliometric, altmetric and patent analysis	Tools for citation, collaboration and trend analysis	Tools for citation analysis, journal analytics and bibliometric indicators

The search query is shown in Fig. 1.

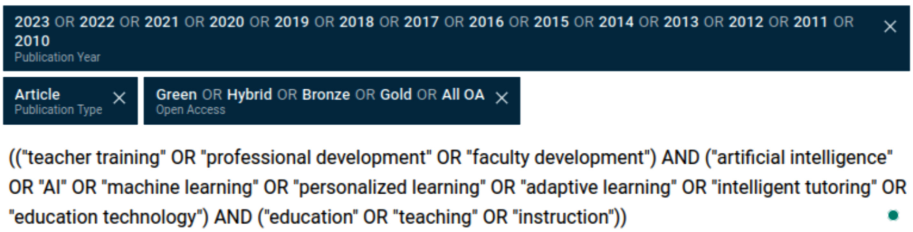

Fig. 1. The search query in the Dimensions database (dated 21.03.2024).

2.3 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria considered are summarised in Table 2.

Table 2. Inclusion and exclusion criteria.

Criteria	Inclusion	Exclusion
Publication years	Articles published between 2010 to 2023	Articles published before 2010 and after 2023
Publication type	Peer-reviewed journal articles	Non-journal articles
Language of articles	Documents reported in the English	Documents not reported in the English
Accessibility	Open access documents only	Closed access documents
The focus of the articles	Publications focusing on teacher training or professional development in the context of AI-powered personalized learning	Publications not explicitly addressing teacher training or professional development in relation to AI-powered personalized learning
Population (students/youth)	Students in the teacher's training programs or teachers	Students not majoring in the teacher's training and non-teachers

2.4 Data Extraction

The process of selecting articles for review considered PRISMA guidelines [14] as shown in Fig. 2.

The initial search yielded a total of 170 563 publications. After applying the inclusion and exclusion criteria, 347 publications were selected for further analysis. The bibliographic data, including titles, abstracts, keywords, author information, citation counts, and other relevant metadata, were extracted from Dimensions and imported into the bibliometric analysis software VOSviewer.

2.5 Data Visualization

VOSviewer 1.6.20 [5] was employed for various bibliometric analyses, including [7, 18]: co-authorship analysis to identify collaboration patterns among researchers, institutions, and countries, unveiling prominent research clusters and influential contributors; co-occurrence analysis to examine keyword frequency and co-occurrence, providing insights into major themes, topics, and emerging trends; citation analysis to evaluate influential publications, authors, and journals, identifying seminal works and key contributors shaping the discourse. VOSviewer facilitated network and overlay visualization analyses of citation networks for authors, journals, organizations, countries, and keyword co-occurrences. Co-authorship relationships and clusters across organizations and

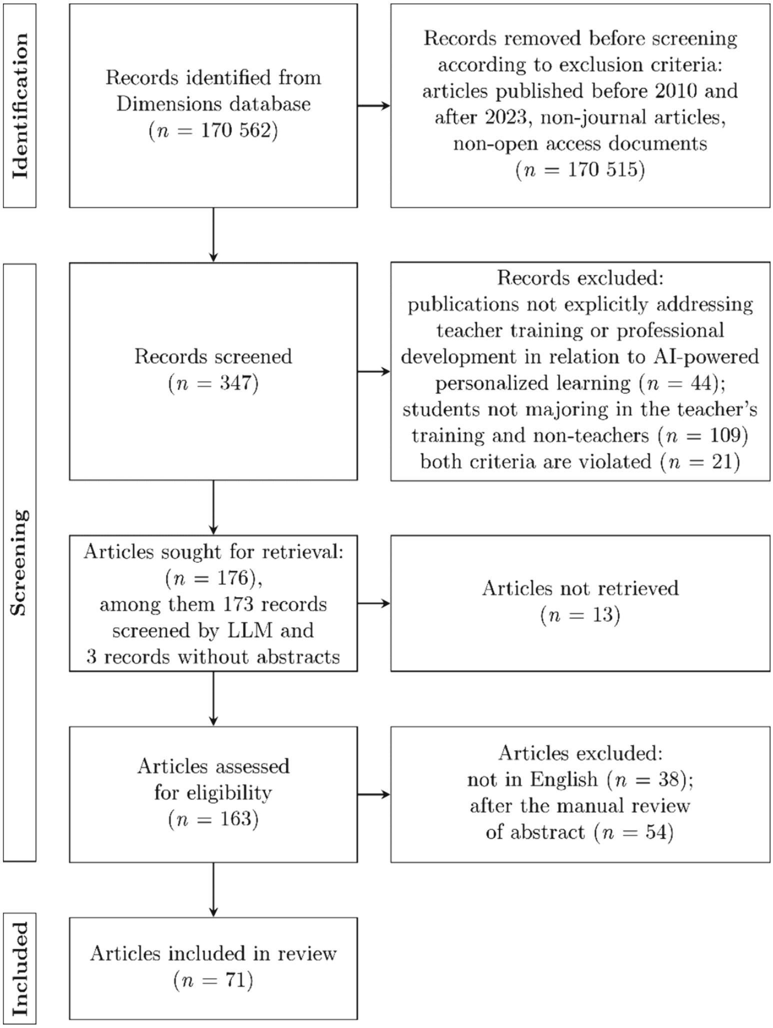

Fig. 2. Flow diagram for the systematic review following the PRISMA statement.

countries were established based on the strength of collaboration links. The analysis provided a comprehensive overview of the research landscape in the field.

3 Experiment

To automate the screening stage, we used large language models (LLM) to evaluate study abstracts according to predefined inclusion/exclusion criteria. This stage of screening is a critical bottleneck because it requires individual abstract review.

This problem can be formally described as follows. Given: a database of N scientific papers (articles, dissertations, books and their parts, reports) represented by their annotations $A_1, A_2, \ldots, A_N$; inclusion criteria $C_1, C_2, \ldots, C_m$; exclusion criteria $E_1, E_2, \ldots, E_n$.

We need a model M that can take as input each annotation A_i and the criteria $C_1, C_2,\ldots, C_m, E_1, E_2,\ldots, E_n$ and output a label L_i indicating whether the study meets the criteria or not:

$$M\left(A_i, C_1, C_2, \ldots, C_m, E_1, E_2, \ldots, E_n\right) = L_i,$$

where L_i can take one of k values: meets all the inclusion criteria and does not meet the exclusion criteria; violates the inclusion criteria C_j; violates the exclusion criteria E_k; violates some of the inclusion and exclusion criteria, etc.

We assume that large language models pre-trained on large text corpora can efficiently perform this classification, given the semantic meaning of the annotations and criteria. To test this assumption, we created a program using the OpenAI API to access the LLM GPT-3.5 Turbo, which reads a set of 347 articles with their annotations, article IDs, and two inclusion criteria (Appendix A):

C_1: *focus* – the article is dedicated to teacher training or professional development in the field of personalized learning based on artificial intelligence;

C_2: *population* – the article deals with teachers or future teachers – students enrolled in teacher education programs.

For each article, the abstract text was provided as a hint for the LLM, along with instructions to analyze whether the criteria were met, violated, or if there was insufficient information. In response, LLM had to classify each article into one of four categories: meets both criteria (1 1), violates C1 (0 1), violates C2 (1 0), or violates both criteria (0 0).

LLM classified 173 out of 347 articles as meeting both inclusion criteria (Table 3).

Table 3. Results of screening using LLM.

Screening results	Number of papers
Excluded by violation of criteria C_1	44
Excluded by violation of criteria C_2	109
Excluded by violation both criteria	21
Included	173

In addition, 3 articles were erroneously identified as excluded due to the lack of annotations in the data source. A total of 176 articles were selected for full-text search after accounting for this error.

To assess accuracy, we manually reviewed a sample of 50 articles in all four categories. The accuracy for articles that met the criteria was 67%. We found more false positives (44%) than false negatives (16%). Due to the high proportion of false positives in the sample, a full manual review of the 125 selected articles was performed, which revealed that 54 articles (43.2%) included by LLM actually violated one of the inclusion criteria. Finally, 71 articles were included in (see GitHub repository [10] for details).

4 Results

4.1 Global Trends on Research About Teacher Training or Professional Development in the Context of AI-Powered Personalized Learning

The dynamic of publications on the problem under study is shown in Fig. 3. The increased interest of scientists in this issue in 2023 can be attributed to several reasons: first of all, the growth of opportunities for practical experience in using AI servers: ChatGPT was presented to the general public in November 2022 [13], Microsoft Copilot in May 2023 [9], and Google Bard in February, 2023 [15]. The second reason is the impact of the COVID-19 pandemic, which accelerated the transition to blended learning and the use of online tools in the educational process. It has also spurred a growing interest in innovative teaching methods, including AI-powered personalized learning.

4.2 Authors with Higher Citations

The results of the analysis of authors by citations are summarised in Table 4. The most cited authors are Gisela Cebrian, Jordi Mogas, and Ramon Palau, and their publication "The Smart Classroom as a Means to the Development of ESD Methodologies" [4] has been cited 79 times.

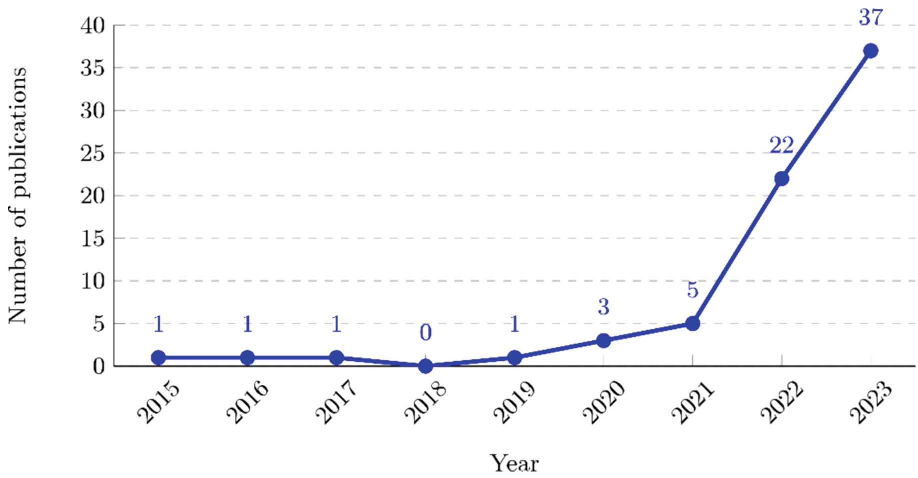

Fig. 3. Trends on publications about teacher training or professional development in the context of AI-powered personalized learning.

To analyze collaboration between authors, we selected authors of publications that have at least 10 citations; 65 authors meet this condition. However, only 16 authors form a network (Fig. 4).

Table 4. Authors with the highest citations.

Rank	Author	Citations	Rank	Author	Citations
1	Cebrian, Gisela	79	17	Fasold, Frowin	53
2	Mogas, Jordi	79	18	Furley, Philip	53
3	Palau, Ramon	79	19	Griffin, Linda	53
4	Gonzalez-Calatayud, Victor	66	20	Hillmann, Wolfgang	53
5	Prendes-Espinosa, Paz	66	21	Huttermann, Stefanie	53
6	Roig-Vila, Rosabel	66	22	Klein-Soetebier, Timo	53
7	Alexandron, Giora	58	23	Konig, Stefan	53
8	Ariely, Moriah	58	24	Memmert, Daniel	53
9	Cukurova, Mutlu	58	25	Nopp, Stephan	53
10	Nazaretsky, Tanya	58	26	Rathschlag, Marco	53
11	Ng, Davy Tsz Kit	55	27	Schul, Karsten	53
12	Su, Jiahong	55	28	Schwab, Sebastian	53
13	Zhong, Yuchun	55	29	Thorpe, Rod	53
14	Almond, Len	53	30	Kirschner, Paul A	36
15	Bunker, David	53	31	Wasson, Barbara	36
16	Butler, Joy	53			

4.3 Organisations with Highest Citations

The analysis was made based on the minimum number of 10 citations in the organisation, and the results are presented in Table 5. The University College London (UCL) has 103 citations, significantly higher than the other organizations. This highlights UCL's strong research output and impact in the field of study. Four organizations – Miguel Hernandez University, University of Alicante, University of Murcia, and the Weizmann Institute of Science – have between 58 and 66 citations each, placing them in the next tier after UCL. Several universities from the UK (Loughborough University, St. Mary's University College), Germany (German Sport University, University of Education Weingarten), and North America (University of British Columbia, University of Massachusetts Amherst) also feature prominently in the top citations, indicating their research strength in this field.

A few universities from Asia (University of Hong Kong, Chinese University of Hong Kong), Europe (Lulea University of Technology, University of Eastern Finland, Open University in the Netherlands, University of Bergen), and the Middle East (Prince Sultan University, University of Sahiwal) have modest citation counts compared to the top organizations but still meet the minimum threshold of 10 citations.

The presence of organizations from diverse geographical regions suggests that the field of study has a global reach and research interest. It is worth noting that the citation count is just one metric for evaluating research output and impact. Other factors, such

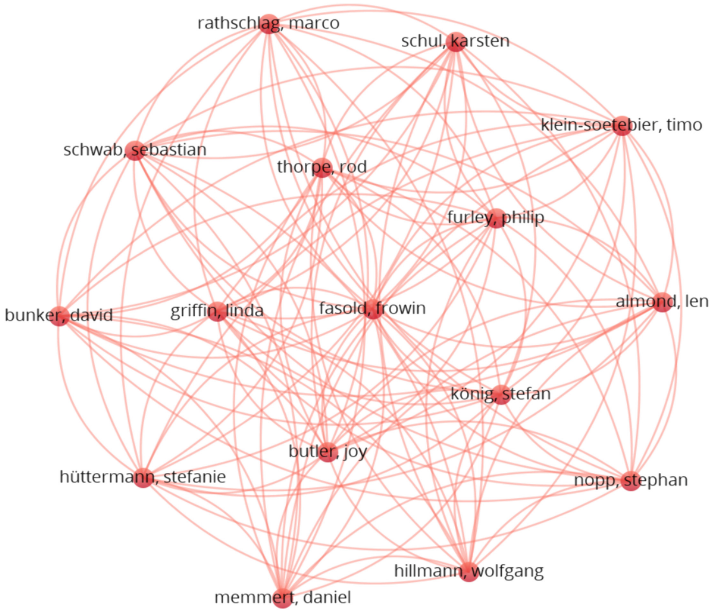

Fig. 4. Network of cooperation between authors in teacher training or professional development in the context of AI-powered personalized learning.

as the quality of the research, its novelty, and its real-world applications, should also be considered.

To analyze collaboration between 72 organisations, we selected organisations that have at least 10 citations; 26 organisations meet this condition. However, only 6 organisations form a network (Fig. 5).

Table 5. Organisations with the highest citations.

Rank	Organisations	Citations
1	University College London	103
2	Miguel Hernandez University	66
3	University of Alicante	66
4	University of Murcia	66
5	Weizmann Institute of Science	58
6	University of Hong Kong	55
7	German Sport University	53
8	Loughborough University	53

(*continued*)

Table 5. (*continued*)

Rank	Organisations	Citations
9	St. Mary's University College	53
10	University of British Columbia	53
11	University of Education Weingarten	53
12	University of Massachusetts Amherst	53
13	Open University in the Netherlands	36
14	University of Bergen	36
15	Lulea University of Technology	29
16	School of Applied Educational Science and Teacher Education	29
17	University of Eastern Finland	29
18	Chinese University of Hong Kong	25
19	Nanjing Normal University	24
20	Prince Sultan University	20
21	University of Sahiwal	20
22	Washington State University	18
23	University of Potsdam	17
24	Education University of Hong Kong	10
25	Hong Kong Baptist University	10
26	Lingnan University	10

4.4 Countries with Higher Publications

The bibliometric coupling analysis was made to identify popular countries and collaborative patterns in research publications. The analysis was based on the minimum number of 1 document of the country and the minimum of 1 citation of the country, whereby out of 27 countries, 22 met the threshold. The findings are presented in Table 6.

Table 6 reveals an interesting interplay between the number of documents published (publication activity) and the number of citations received (citation impact). The United Kingdom leads with the highest number of documents (7) but is followed closely by China (7) with slightly fewer citations (130 vs. 165). This suggests the UK produces a higher volume of research, while China's research might be more impactful based on citations. The United Kingdom, China, and the United States are the top three countries based on document count and citations. The number of documents and citations between the top five and the remaining countries significantly drops, which might indicate a concentration of research activity in a select group of nations.

Fig. 5. Network of cooperation between HEIs in the field of AI.

Table 6. Countries with the highest number of documents and citations.

Rank	Countries	Documents	Citations	Rank	Countries	Documents	Citations
1	United Kingdom	7	165	12	Norway	1	36
2	China	7	130	13	Finland	1	29
3	United States	6	83	14	Pakistan	1	20
4	Spain	5	71	15	Philippines	1	9
5	Germany	4	74	16	Romania	1	9
6	Canada	2	54	17	South Africa	1	7
7	Sweden	2	37	18	Lebanon	1	6
8	Saudi Arabia	2	27	19	Qatar	1	6
9	Egypt	2	7	20	Ukraine	1	3
10	Israel	1	58	21	Japan	1	1
11	Netherlands	1	36	22	Switzerland	1	1

4.5 Sources with Higher Publications

Further analysis was made to identify popular sources. The results are presented in Table 7. Leading sources include journals focused on educational technology (Education and Information Technologies, Computers and Education Artificial Intelligence, British Journal of Educational Technology), indicating a strong emphasis on the technological aspects of teacher training. The presence of the AAAI Conference on Artificial Intelligence proceedings signifies a focus on the underlying AI principles applied to personalized learning.

Interestingly, publications in Sustainability appear high on citations despite having fewer documents. This suggests that research exploring the long-term societal and environmental impacts of AI-powered learning is influential. The inclusion of journals like Wireless Communications and Mobile Computing indicates an exploration of how mobile technologies can facilitate personalized learning and the training needed for teachers to leverage them.

Table 7. Sources with the highest number of documents and citations.

Rank	Sources	Documents	Citations
1	Education and Information Technologies	6	76
2	Proceedings of the AAAI Conference on Artificial Intelligence	5	58
3	Computers and Education Artificial Intelligence	4	75
4	International Journal of Artificial Intelligence in Education	3	31
5	Sustainability	2	87
6	Wireless Communications and Mobile Computing	2	31
7	Applied Sciences	1	66
8	British Journal of Educational Technology	1	58
9	Research Quarterly for Exercise and Sport	1	53
10	TechTrends	1	36
11	Contemporary Educational Technology	1	20
12	Center for Educational Policy Studies Journal	1	18
13	Journal of Science Education and Technology	1	17

While publications in the International Journal of Artificial Intelligence in Education are present, a relatively lower document count suggests a research gap directly focused on AI's pedagogical implications in education. The presence of seemingly unrelated journals like Research Quarterly for Exercise and Sport warrants further investigation. Perhaps these studies explore the impact of personalized learning on student well-being or the use of AI for personalized physical education programs.

4.6 Co-occurrence of Keywords

The co-occurrence analysis of keywords was carried out to explore the popular key areas associated with the research topic. The analysis was based on a minimum number of ten occurrences of a term, where out of 2337 terms, 50 met the threshold. A relevance score was calculated for each of the 50 terms, and the selection of 30 terms was based on the default choice of 60% of the most relevant terms. 4 general words were not selected: article, paper, role, and use. The rest of the keywords (26) are presented in Fig. 6.

We use 3 basic techniques to analyse the keyword map:

1. Cluster analysis:

- The keywords seem to be grouped into five distinct clusters, each represented by a different colour.
- Cluster 1 (red) includes keywords such as "experience", "gai", "impact", "integration", "opportunity", and "strategy" related to the overall impact, opportunities, and strategies associated with AI-powered personalized learning.
- Cluster 2 (green) contains keywords like "ai literacy", "analysis", "framework", "school", and "teaching" related to the frameworks, analysis, and teaching aspects of AI-powered personalized learning.
- Cluster 3 (blue) includes keywords such as "aiedtech", "evidence", "importance", and "system" related to the evidence, importance, and systems involved in AI-powered personalized learning.
- Cluster 4 (yellow) includes keywords such as "activity", "classroom", "curriculum", and "researcher" related to the classroom environment, curriculum, and research aspects of AI-powered personalized learning.
- Cluster 5 (purple) contains keywords like "chatgpt", "model", and "reflection" related to specific AI models, such as ChatGPT, and the reflection on their use in personalized learning.

2. Keyword occurrence and strength:

- The keyword with the highest occurrence is "teacher" (199 occurrences), followed by "technology" (115 occurrences) and "teaching" (52 occurrences). These high occurrences suggest that the research focuses heavily on teachers, technology, and teaching practices in the context of AI-powered personalized learning.
- Keywords with high total link strength, such as "technology" (1178), "model" (521), and "teaching" (626), indicate strong connections and co-occurrences with other keywords, suggesting their central role in the research topic.

3. Temporal and citation analysis:

- The average publication year for most keywords falls around 2022, indicating that the research topic is relatively recent.
- Keywords like "aiedtech" (58 average citations) and "smart classroom" (55.3 average citations) have high average citation counts, suggesting that these are well-established or influential concepts in the field.
- Keywords such as "ai literacy" (1.269 average normalized citations) and "importance" (1.4044 average normalized citations) have relatively high average normalized citation scores, indicating their potential impact and relevance within the research topic.

The keyword map provides insights into the various aspects and dimensions of optimizing teacher training and retraining for the age of AI-powered personalized learning.

It highlights the importance of teachers, technology, teaching practices, classroom environments, curriculum, and specific AI models like ChatGPT. The analysis also suggests that the research topic is relatively recent but has already gained traction, with some influential concepts and well-cited studies emerging.

5 Discussion

Several limitations of this study should be noted. First, the inclusion criteria were formulated in relatively simple semantic units regarding study focus and population. More complex criteria, including study design, details of intervention (population impact), statistical analysis, etc., may be a challenge for current LLM capabilities, but their performance could be improved by query engineering or model refinement based on data from non-LLM systematic reviews. In addition, we did not evaluate the effectiveness of LLM across different research fields: the inclusion/exclusion criteria were provided to the model as hints without being specific to a particular field. Customizing or refining the LLM for each research area may increase efficiency. Despite these limitations, this study highlights the enormous potential of using advanced artificial intelligence models to speed up the work of evidence-based research synthesis. As LLMs are rapidly evolving, they are likely to play an increasingly prominent role in optimizing not only systematic reviews but also other important research activities.

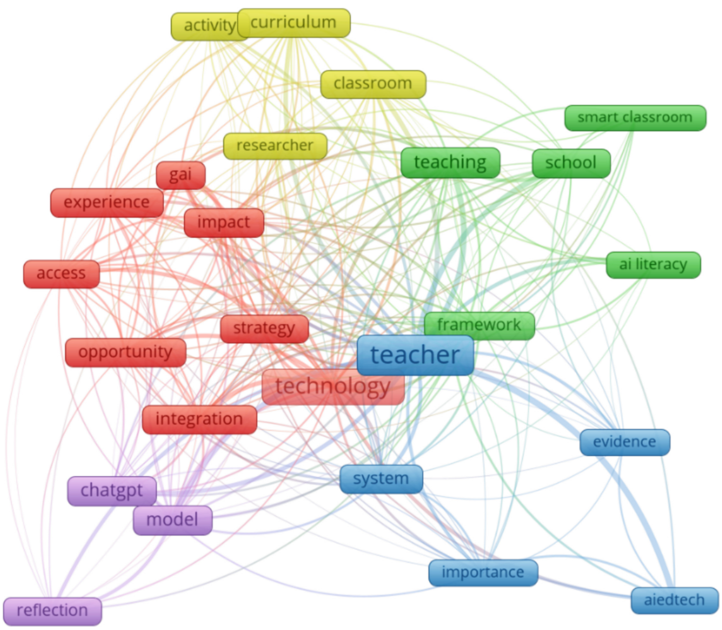

Fig. 6. Network visualisation of keywords on the research topic.

6 Conclusions

This bibliometric analysis has provided a comprehensive overview of the current research landscape on teacher training and retraining in the context of AI-powered personalized learning. By systematically analyzing publications, authors, institutions, countries, sources, and keyword co-occurrences, we have unveiled several key insights and trends. The study has highlighted the recent surge in research interest in this field, particularly in 2023, driven by the growing practical applications of AI technologies and the accelerated adoption of online and blended learning approaches during the COVID-19 pandemic. Influential authors, institutions, and countries have been identified, shedding light on the key contributors shaping the discourse and the geographical distribution of research efforts. The analysis has revealed the multidisciplinary nature of the research, with contributions from diverse fields such as educational technology, artificial intelligence, sustainability, and wireless communications. This diversity underscores the complex and multifaceted nature of the challenge, requiring a synergistic approach from various disciplines. Through keyword co-occurrence analysis, we have uncovered the prevalent themes, concepts, and emerging trends within the research topic. The analysis has highlighted the central focus on teachers, technology, teaching practices, classroom environments, curriculum, and specific AI models like ChatGPT. Identifying these key areas provides a roadmap for future research and a framework for developing comprehensive teacher training and retraining programs. As LLMs develop rapidly, they are likely to play an increasingly prominent role in optimizing not only systematic reviews but also other important research activities. Promising areas include using LLMs for other steps in a systematic review, such as full-text screening, data extraction from studies, risk of bias analysis, and even intelligent synthesis of research findings. Exploring how LLMs can semi-automate the systematic review process in a robust, validated machine learning pipeline (LLMOps) is an exciting area for future research with profound implications for accelerating synthesis-based scientific discovery and evidence-based decision-making. For national educational research, this is another opportunity to move to evidence-based education, which is similar to evidence-based medicine in that it provides an opportunity to make informed decisions about the choice of specific actions (impacts, interventions, etc.) in the educational process, the effectiveness of which in a given context is scientifically proven.

Appendix A. Using OpenAI LLM to Papers' Screening

The following code using OpenAI Python binding 0.28. After getting OpenAI API key (https://help.openai.com/en/articles/4936850-where-do-i-find-my-openai-api-key), the `llm_response` function was created:

```
import openai, os
openai.api_key = os.getenv("OPENAI_API_KEY")

def llm_response(prompt):
  response = openai.ChatCompletion.create(
    model='gpt-3.5-turbo', temperature=0,
    messages=[{'role': 'user', 'content':prompt}])
  return response.choices[0].message['content']
```

To proceed with all papers, the following field were exported: `paper_id` and `abstract`. Therefore, the resulting code contained 347 pairs, first of each is `paper_id` (e.g., `pub.1164411384`), and the second is the paper abstract:

```
all_reviews = [
["pub.1164411384", "Artificial intelligence (AI) has tremendous
potential to change the way we train future health profession-
als. Although AI can provide improved realism, engagement, and
personalization in nursing simulations, it is also important to
address any issues associated with the technology, teaching
methods, and ethical considerations of AI. In nursing simulation
education, AI does not replace the valuable role of nurse educa-
tors but can enhance the educational effectiveness of simulation
by promoting interdisciplinary collaboration, faculty develop-
ment, and learner self-direction. We should continue to explore,
innovate, and adapt our teaching methods to provide nursing stu-
dents with the best possible education."],
# rest 346 rows are skipped
]
```

The following code is intended to classify papers according to inclusion `(1 1)` and exclusion `(0 1, 1 0, 0 0)` criteria:

```
all_sentiments = []
for review in all_reviews:
    paper_id = review[0]
    abstract = review[1]
    prompt = f'''
        You should analyze the abstracts and answer 2 questions:
1. Is this publication focusing on teacher training or profes-
sional development in the context of AI-powered personalized
learning?
2. Is the population the students majoring in the teacher's
training programs or teachers?
Your answer should be "1 1" in case of positive answers on both
questions, "0 0" in case of negative answers, "1 0" in case of
first positive and second negative, and "0 1" vice versa. Don't
add any other text to your answer.
The abstract:
        {abstract}
        '''
    response = llm_response(prompt)
    all_sentiments.append([paper_id, response])

counts = {"1 1": 0, "1 0": 0, "0 1": 0, "0 0": 0}
lists = {"1 1": [], "1 0": [], "0 1": [], "0 0": []}
for paper_id, answer in all_sentiments:
    counts[answer] += 1
    lists[answer].append(paper_id)

print(f"Included {counts['1 1']} records: {lists['1 1']}")
print(f"Excluded by violation of 1st criteria {counts['0 1']}
records: {lists['0 1']}")
print(f"Excluded by violation of 2nd criteria {counts['1 0']}
records: {lists['1 0']}")
print(f"Excluded by violation both criteria {counts['0 0']} rec-
ords: {lists['0 0']}")
```

References

1. Publications - Dimensions (2024). https://app.dimensions.ai/discover/publication. Accessed 12 May 2024
2. Scopus (2024). https://en.wikipedia.org/wiki/Scopus. Accessed 12 May 2024
3. Web of Science (2024). https://en.wikipedia.org/wiki/Web_of_Science. Accessed 12 May 2024
4. Cebrián, G., Palau, R., Mogas, J.: The smart classroom as a means to the development of ESD methodologies. Sustainability **12**(7), 3010 (2020). https://doi.org/10.3390/su12073010
5. Centre for Science and Technology Studies, Leiden University, The Netherlands: VOSviewer - Visualizing scientific landscapes (2024). https://www.vosviewer.com/. Accessed 12 May 2024

6. Demianenko, V.B.: Principles of a unified open personalized computer-integrated learning environment for the Junior Academy of Sciences of Ukraine. Educ. Dimension **8**, 187–211 (2023). https://doi.org/10.31812/ed.599
7. van Eck, N.J., Waltman, L.: VOSviewer Manual: Manual for VOSviewer version 1.6.20. Universiteit Leiden, October 2023. https://tinyurl.com/mry32wb5. Accessed 12 May 2024
8. Fadieieva, L.O.: Enhancing adaptive learning with Moodle's machine learning. Educ. Dimension **5**, 1–7 (2021). https://doi.org/10.31812/ed.625
9. Mehdi, Y.: Announcing the next wave of AI innovation with Microsoft Bing and Edge, May 2023. https://tinyurl.com/47zrwcjw. Accessed 12 May 2024
10. Mintii, I.S., Semerikov, S.O.: Optimizing Teacher Training and Retraining for the Age of AI-Powered Personalized Learning: A Bibliometric Analysis (Raw and Processed Data, May 2024. https://github.com/ssemerikov/ITEST2024_MintiiSemerikov. Accessed 12 May 2024
11. Mintii, I.S.: Blended learning for teacher training: benefits, challenges, and recommendations. Educ. Dimension **9**, 1–12 (2023). https://doi.org/10.31812/ed.581
12. Ndibalema, P.M.: The growth of cyberbullying among youth in higher learning institutions: a bibliometric analysis. Educ. Dimension **10**, 143–166 (2024). https://doi.org/10.55056/ed.700
13. OpenAI: Introducing ChatGPT, November 2022. https://openai.com/blog/chatgpt. Accessed 12 May 2024
14. Page, M.J., et al.: The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ **372**, n71 (2021). https://doi.org/10.1136/bmj.n71
15. Pichai, S.: An important next step on our AI journey, February 2023. https://blog.google/technology/ai/bard-google-ai-search-updates/. Accessed 12 May 2024
16. Semerikov, S.O., Striuk, A.M., Shalatska, H.M.: AI-assisted language education: critical review. Educ. Dimension **4**, 1–7 (2021). https://doi.org/10.31812/ed.623
17. Semerikov, S.O., et al.: Development of the computer vision system based on machine learning for educational purposes. Educ. Dimension **5**, 8–60 (2021). https://doi.org/10.31812/educdim.4717
18. Smyrnova-Trybulska, E., Morze, N., Kuzminska, O., Kommers, P.: Mapping and visualization: selected examples of international research networks. J. Inf. Commun. Ethics Soc. **16**(4), 381–400 (2018). https://doi.org/10.1108/JICES-03-2018-0028