Beyond Text-to-Text: An Overview of Multimodal and Generative Artificial Intelligence for Education Using Topic Modeling

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Abstract

Generative artificial intelligence (GenAI) can reshape education and learning. While large language models (LLMs) like ChatGPT dominate current educational research, multimodal capabilities-such as text-to-speech and text-to-image—are less explored. This study uses topic modeling to map the research landscape of multimodal and generative AI in education. An extensive literature search yielded 4175 articles. Employing a topic modeling approach, latent topics were extracted, resulting in 38 interpretable topics organized into 14 thematic areas. Findings indicate a predominant focus on text-to-text models in educational contexts, with other modalities underexplored, overlooking the broader potential of multimodal approaches. The results suggest a research gap, stressing the importance of more balanced attention across different AI modalities and educational levels. In summary, this research provides an overview of current trends in generative AI for education, underlining opportunities for future exploration of multimodal technologies to fully realize the transformative potential of artificial intelligence in education.

CCS Concepts

• Applied computing \rightarrow Education; • Computing methodologies \rightarrow Artificial intelligence; Information extraction; • General and reference \rightarrow Surveys and overviews.

Keywords

artificial intelligence, education, topic modeling, large language models, multimodal

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1 Introduction

Whether you have experience in Education 2.0 [18], Education 3.0 [91], Education 4.0 [66], Education 5.0 [55], or even already in Education 6.0 [58], you might have thought of how artificial intelligence (AI) could acceptably and responsibly [62] realize its "potential for reshaping the core foundations of education, teaching and learning" [85, p. 3]. Recently, the UNESCO *Guidance for generative AI in*



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education and research noted that developments in generative AI might trigger a transformative change in established educational systems and their foundations [86]. Generative AI refers to models capable of producing text, images, video, computer code, and other content modalities by utilizing the data on which they were trained. These advanced technologies applied in educational contexts create opportunities and challenges, with regulatory efforts trying to address emergent issues. At the same time, the uneven distribution of research-based knowledge and the influence of market leaders pose questions for the future of pedagogy. Thus, this study seeks to shed light on artificial intelligence for education by synthesizing research literature using topic modeling to answer the following research question: What is the high-level research landscape of multimodal approaches and generative AI in education?

2 Background

Various AI-driven pedagogical and technological solutions are emerging at an accelerating pace, creating both possibilities and tensions [3, 62]. At the same time, organizations and legislators, such as the EU, strive to keep up with opportunities and challenges. For example, the recently published EU Regulation No. 2024/1689 (Artificial Intelligence Act), which aims to harmonize rules on AI, regulates issues such as emotion recognition in educational contexts. From the educational standpoint, a key challenge arises when research-based knowledge is unevenly distributed across different perspectives and technologies, with market leaders heavily impacting the landscape of AI in education [e.g., 89]. For instance, if technological advances primarily drive various pedagogical approaches, it is crucial to recognize the influence this has. It is equally important to discern what aspects of these technologies are hype and which areas risk being overlooked [e.g., 37, 54, 80, 97].

From the historical perspective, the fields of artificial intelligence and education have been closely linked since the inception of AI, with early AI pioneers contributing to both areas by using AI to understand and improve human learning, a perspective that has since been argued to be diminished but still revivable [24]. Also, computational methods for performing transformations between different data modalities have existed, for example, for text-to-text, text-tospeech, and speech-to-text since the 1950s [22, 38, 44] and text to image since the 2000s [2]. Recently, deep learning has allowed the development of other transformations like text-to-video, video-totext [67], and text-to-music [10]. These multimodal capabilities are suggested to benefit education [12], and multimodal AI is claimed to possess even an "immense" [51, p. 2] and "vast" [57, p. 271] potential. Thus, both AI research and educational research together [15] should investigate the multimodal and generative capabilities of these so-called foundation models [6] to ensure "human-centered and pedagogically appropriate interaction" [86, p. 29].

Recently, reviews have identified main application areas of AI in education like assessment, administration, prediction, AI assistants, content delivery, intelligent tutoring systems, and managing student learning, while also highlighting challenges such as negative perceptions, technology skills gaps, ethical concerns, and AI tool design issues [19, 20]. Higher education and the educational domains of medical, language, engineering, and computing education have received the most attention in research [19, 97]. Future research should examine transparency, bias mitigation, curriculum design, and ethical usage to enhance educational practices across various disciplines [5]. In general, an extensive body of research on AI in education highlights a broad range of applications, theories, and methodologies [e.g., 92].

However, the development of AI technologies for education is still argued to lag behind, with most tools being simple, singlepurpose, and not tailored to interdisciplinary learning needs, highlighting the need for researchers to examine and design more advanced, versatile, and useful AI tools for education [15, 75]. For example, while the long-existed text-to-speech technology has shown promising potential for improving writing performance, spelling, and reading comprehension among adolescents with learning difficulties, the amount of high-quality research in this area remains limited, indicating the need for further investigation [54]. In general, multimodal capabilities of generative AI in educational research have received limited attention because existing research has focused primarily on text-to-text models [12, 54]. Also, recent research [e.g., 37, 97] observed that prior studies have often suffered from inconsistencies and weaknesses in the search strategies and ambiguity in the concept of AI. Thus, the novelty of this research was the extensive search string incorporating a relatively broad set of multimodal capabilities of generative AI.

3 Materials and methods

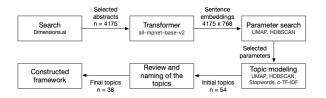


Figure 1: Topic modeling process

3.1 Data collection

Data collection was conducted in August 2024 using Dimensions.ai service, and a complementary search was conducted using Scopus and Web of Science (WOS). However, the complementary search did not yield any new results. Dimensions.ai is argued to provide an extensive literature coverage [e.g., 83, 90]. Also, when selecting the example articles, we found that at least one article, [71], was found only using Dimensions.ai.

Focusing on student perspective, the following search string was used to search articles, proceedings, and book chapters based on title and abstract with no limitations to publishing year:

(education OR student OR school) AND ('generative ai' OR 'generative artificial intelligence' OR genai OR LLM OR 'large language model' OR 'text-to-text' OR 'text-to-video' OR 'text-to-audio' <COMBINATIONS>

The last part of the search string *COMBINATIONS>* consisted of all combinations of different modalities between text, video, audio, voice, sound, music, data, image, speech, graph, table, emotion, language, and gesture. Notably, to allow more unbiased review of technologies, no service names (e.g., ChatGPT) were included in the search string. The initial search yielded 4475 results. After removing results that did not contain a Document Object Identifier (DOI) or abstract, the final dataset consisted of 4175 articles, forming the text corpus for topic modeling (Figure 1). 95% of the articles were published after 2014. The earliest relevant article in this corpus was from 1983, mentioning a computational approach for transforming data modalities in an educational context that dealt with text-to-speech support for visually impaired students [63].

3.2 Topic modeling

To extract latent topics from the text corpus (Figure 1), we applied the BERTopic approach [32], which has been suggested to be able to generate novel insight and encode contextual information by relying on sentence transformers and embeddings [26]. BERTopic approach has been utilized, for example, to explore dynamics of AI applications [70] and interdisciplinary topics in science [93].

Firstly, we created transformer-based embeddings of the abstracts using the general-purpose sentence transformer *all-mpnet-base-v2*¹. The transformer has been trained, among many other datasets, using over 116 million English-language academic papers from The Semantic Scholar Open Research Corpus (S2ORC)² [50]. Secondly, the created 768-dimensional document embeddings were then dimensional reduced using Uniform Manifold Approximation and Projection (UMAP) [56]. Thirdly, using the reduced embeddings, the documents were clustered by applying the Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDB-SCAN) algorithm [8]. Finally, English stopwords were removed, and the class-based Term Frequency-Inverse Document Frequency (c-TF-IDF) approach was used to generate initial topics. Topics were reviewed and interpreted by the authors.

Both UMAP and HDBSCAN require several hyperparameters to perform dimensionality reduction and clustering. Instead of arbitrarily choosing the parameters, topic count, or topic size, we employed a parameter search approach by randomly sampling combinations of parameters for UMAP and HDBSCAN (Figure 1). This allowed us to explore various parameters without exhaustively testing every combination. Specifically, we performed 5000 iterations, each time selecting random values for key parameters, such as the number of neighbors (range [2, 55]), minimum distance (0.0 or 0.1), and distance metrics (Manhattan, Euclidean, cosine) for UMAP, as well as the minimum cluster size (range [2, 55]), minimum samples (range [2, 55]), clustering method (leaf, eom), and distance metrics (Manhattan, Euclidean) for HDBSCAN (Figure 4).

 $^{^1 \}rm https://web.archive.org/web/20240823053754/https://huggingface.co/sentence-transformers/all-mpnet-base-v2$

²https://github.com/allenai/s2orc

The optimal hyperparameter solution for this research was selected based on the Density-based Clustering Validation (DBCV) index[60], topic count, and out-of-topic abstract count. The DBCV index is a metric that can be used to assess the quality of clustering by evaluating the density-based separation between clusters and the cohesion within clusters. The optimal solution aimed to obtain a feasible number of topics while leaving the minimum number of abstracts not assigned to any topic. In other words, a clustering solution (i.e., number of topics) for each solution in the set of all clustering solutions *S* that minimizes the number of out-of-topic documents and maximizes the DBCV index was assessed as follows:

$$S^* = \arg \max_{S_i \in S'} D(S_i)$$
 where $S' = \arg \min_{S_i \in S} O(S_i)$,

where $O(S_i)$ represent the number of out-of-topic (i.e., not assigned abstracts) documents for solution S_i and $D(S_i)$ represent the DBCV index for solution S_i . Figure 3 depicts the solutions in S^* for solutions having the number of topics]1, 150[. In this research, the number of topics less than 20 were considered too general, and more than 150 were considered not feasible for a human to interpret qualitatively. In the selected topic model, the interpretability of a single topic was assessed using information entropy: the lower the entropy of a topic, the more likely it is to be considered a valid topic [93]. Lastly, the topics were arranged as a thematic map combining similar topics to higher-level representations [7].

4 Results

4.1 Different modalities

OpenAI ChatGPT showed the most occurrences in the corpus compared to similar types of generative AI services like Google Gemini or Bard, Microsoft Copilot, Anthropic Claude, and Perplexity.ai (Table 1). However, some keywords can refer to a form of generative AI with various meanings in the literature. The term copilot is used, for example, to denote various interactive companions "that can follow diverse instructions and coherently and accurately answer complex open-ended questions in natural language" [51, p. 2]. On the other hand, copilot can also refer to a specific software like Microsoft Copilot [e.g., 31] or GitHub Copilot [e.g., 88]. Similarly, the term perplexity can refer to an information theoretical measure [e.g., 95] or a software called Perplexity.ai [e.g., 73]. While there is a lack of precise conventions for naming used technologies, OpenAI ChatGPT seems to dominate the research concerning LLMs in education, which is not surprising considering the simplicity of its operation [e.g., 74] and prior similar review results [e.g., 5]. Including specific product names in the literature, search string can yield different results, but this research addressed literature that explicitly mentioned different generative models instead of specific software services.

Text-to-speech was the next common keyword after language models followed by text-to-image, text-to-text, and speech-to-text, reflecting the maturity of technologies [i.e., 2, 22, 38, 44] and diffusion of innovations into educational domain (Table 1, Figure 2). Research suggests that text-to-speech and speech-to-text technologies can be used, for example, to support reading comprehension [78] and children who have writing difficulties [43]. Text-to-image technology has been utilized in education, for example, for supporting creative ideation [49], facilitating understanding of concepts in

Table 1: The number of titles/abstracts mentioning selected keywords in the corpus (including different forms like llm, llms, generative ai, genai etc.)

Keyword	Occurrences
large language model	3645
generative artificial intelligence	2177
chatgpt	1471
text to speech	461
(Continuing in Figure 2)	

structural engineering [9], and creating facial images for medical education [27]. Image-to-image technology has been utilized for creating photorealistic macromolecular visualization for educational purposes [25]. The emerging text-to-video and its manifestations like OpenAI Sora were explored for a possibility to augment and personalize learning and facilitate AI-driven content creation [1, 57]. One multimodal approach was found that used several multimodal approaches to create teaching materials [12].

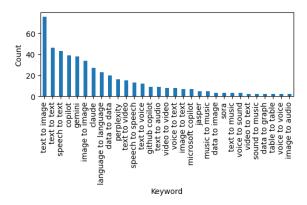


Figure 2: The number $(n \ge 2)$ of titles/abstracts mentioning different keywords in the corpus

4.2 Topic modeling

A topic modeling approach was used to further summarize the corpus of abstracts. The first step was to obtain a reasonable set of hyperparameters for modeling by randomly sampling combinations of parameters. Figure 3 shows the best solutions for each number of clusters (i.e., the number of topics) based on minimizing the number of not assigned abstracts and maximizing the DBCV index. A feasible number of topics, with a topic count of 54, was selected as the optimal solution for obtained hyperparameters and study context. A parallel coordinate plot, Figure 4, depicts the hyperparameter space showing all the parameter solutions by DBCV index and the selected hyperparameter solution.

Using the selected parameters, topic modeling yielded 54 initial topics consisting of 85% of the initial corpus of abstracts. Abstracts not assigned to any topic (15%) were not forced to any topic after modeling because forcing them to the topic model might have introduced additional errors. The information entropy of the topics

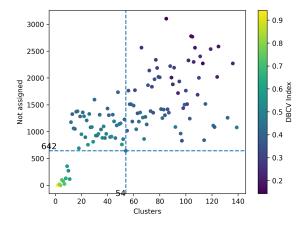


Figure 3: Best topic modeling solution for the number of clusters between]1, 150[

ranged from 3.083 to 3.367, and none showed significantly higher (2 x SD) information entropy (M = 3.290, SD = 0.062), suggesting that all were equally valid topics. After reviewing and interpreting the topics, eight were merged with others because of similar representation and content. Eight topics were deemed uninterpretable and removed from the final set. Table 2 shows the final set of representations and example articles of 38 topics consisting of 74% of the initial corpus of abstracts. When possible, the example articles were chosen based on the publication year 2024 and open-access publication type, allowing interested readers unrestricted access.

The topics were further arranged as a thematic map of research on generative AI in education, depicting 14 prominent thematic focus areas, each with corresponding lower-level topics (Figure 5). The number of abstracts assigned to each topic is indicative and serves as a general representation, but not all abstracts may perfectly align with or be definitive representatives of the corresponding topic. However, the number of topics identified can provide insights into each research area's relative magnitude and prominence.

Within the *Domains* theme, generative AI was applied across educational domains, for example, to enhance problem-solving in specialized fields like geotechnical engineering [e.g., 11], improve learning strategies in chemistry [e.g., 82] and business research education [e.g., 4], adapt curriculum design and content creation in engineering education [e.g., 96], support interdisciplinary and AI literacy-focused higher education [e.g., 13], and simplify complex health education materials for improved accessibility [e.g., 72]. The *Personalized Learning Support* theme is related to integrating tools like text-to-speech [e.g., 94], sentiment and emotion analysis [e.g., 65], and feedback and tutoring systems [e.g., 47, 48] to enhance individual learning experiences. *Problem Solving* includes areas like mathematical and physics problem-solving [e.g., 71], simulations [e.g., 28], and explanations [e.g., 17].

Technology Adoption concerns factors influencing the acceptance of AI [e.g., 76], for example, using sentiment analysis in social media [e.g., 53], while *Professional Development* centers on teacher education and professional preparedness [e.g., 79]. The theme of

Creativity explores generative AI for facilitating creativity, for example, in visual design and art using technologies like text-to-image generation [e.g., 41, 87]. Serious Games focuses on using generative AI in developing educational games [e.g., 84], and Tools and Content addresses the utilization of AI for content design [e.g., 68], automated question generation [e.g., 33], and managing information [e.g., 23].

Assessment explores grading, performance evaluation, and assessment using generative AI [e.g., 30] and the implications for academic integrity [e.g., 52]. Ethics and security encompasses concerns on generative AI [e.g., 99] and critical perspectives on using AI tools like chatbots [e.g., 40] in educational and research contexts, addressing their impact on integrity, privacy, and academic principles [e.g., 61]. Closely related Integrity theme highlights issues about AI-generated content and its impact on academic integrity [e.g., 45], particularly in detecting AI-generated text [e.g., 29] and code submissions [e.g., 64]. The theme Chatbots examines the use of AI-driven chatbots for education [e.g., 34, 77], for example, in language learning [e.g., 98]. Lastly, Language Learning concerns using AI for language teaching [e.g., 59], translation and intercultural skills, and educational interactions [e.g., 21].

5 Discussion and conclusion

This study aimed to explore the landscape of multimodal and generative AI in education by employing a topic modeling approach, identifying 38 research topics. The thematic analysis synthesized the topics into 14 key focus areas (capitalized and in different colors in Figure 5), each encompassing various lower-level topics (in lowercase in Figure 5), offering insights into the prominence and scale of different research domains. The findings suggest that generative AI technologies, particularly OpenAI ChatGPT, dominate educational research, reflecting the focused interest and rapid adoption of LLMs in academic contexts. However, the results also highlight the potential of AI incorporating different modalities (e.g., text-to-speech [78], speech-to-text [46], and text-to-image [41]) in personalized learning, problem-solving, and creativity, areas that have received less attention compared to LLMs dealing with text-to-text transformations.

The results align and support the findings from the other recent literature, arguing that there is a need to extend the research to other technologies across educational levels. To emphasize, the next common technology after LLMs found in this research, text-to-speech, is argued to have a limited number of high-quality research [54]. Also, the only educational level identified at a topic level in this research was higher education, which supports the claims that there is limited research on other levels (e.g., K-12) [20, 87, 97].

Generative AI can challenge the foundational aspects of learning and education. Some authors argue that generative AI reflects a surface approach to learning and a "functionalist and economist vision of society" [16, p. 231]. Thus, to protect and enhance student agency [35, 36], we need to have a broad understanding of different AI technologies [86]. For example, while LLMs can offer assistance in drafting and editing [48], they also raise questions about academic integrity, as the ease of generating text may compromise the originality of student work [29, 52]. In other words, there seems to be a tension between using LLMs as supportive tools to help

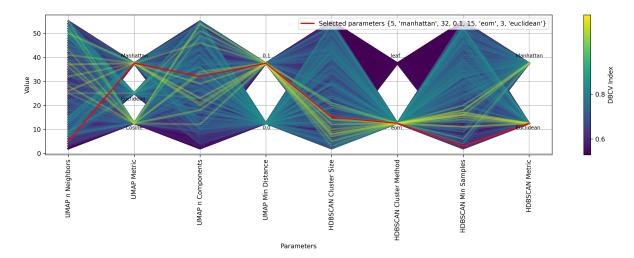


Figure 4: A parallel coordinate plot depicting the hyperparameter space (n=5000) and the selected parameters. One line represents one set of parameters.



Figure 5: A thematic map of research on generative AI in education based on the topic modeling results

students improve their skills and the growing concerns about plagiarism and the authenticity of student work generated through these technologies.

For students creating new knowledge in the AI era, the challenge is at the same time mastering the subject matter and reusing knowledge acquired through generative AI [16]. AI for education could greatly benefit from AI models deliberately trained to serve educational needs (e.g., EdGPTs) [86]. Also, integrating multimodal AI-driven tools for visual and auditory content could extend possibilities beyond the capabilities of traditional LLMs by offering richer and more dynamic learning experiences. In addition to medical education, language education, and the natural sciences, fields such as the arts, social sciences, and humanities could also benefit from multimodal approaches in generative AI by enhancing creativity [87], critical and creative thinking [41, 81], and interactive learning experiences [4]. Thus, future research could examine the potential

of educationally focused multimodal foundation models that balance knowledge building and knowledge reproduction in different domains of learning end education. Finally, we recommended that educators open-mindedly play around with a broad range of multimodal AI technologies, such as text-to-speech, speech-to-text, and text-to-image. Bravely experimenting with diverse AI technologies could help educators develop their pedagogical AI imagination, enabling them to creatively reimagine pedagogical approaches and design innovative, technology-enhanced learning experiences to enhance personalized learning and support diverse student needs.

This study has its limitations. Topic modeling of a large corpus offers a general and high-level view of the underlying content, leaving more nuanced and emerging topics hidden. The extensive search string used in this study did not capture all variations of product names associated with generative AI technologies. Thus, it is recommended that future research adopt a harmonized approach

to describing the underlying technologies to facilitate more comprehensive coverage and clarity in future reviews. Teachers and teaching were not included as keywords in the initial search, and future studies could concentrate more on generative AI from educators' perspectives. Also, future studies could focus on different themes identified in this research, which might provide a more fine-grained view of generative AI in education. The search string included several technologies, but future studies could include more (e.g., text to sign language [42]).

In conclusion, this research provided an overview of the current research landscape on generative AI in education, highlighting the need to extend the scholarly horizon beyond text-to-text technologies. While LLMs dominate the research, other promising technologies like text-to-speech remain underexplored, suggesting the need for more balanced attention across AI modalities. Nevertheless, LLMs have proven to be powerful tools for building knowledge—after all, also this research extensively utilized them.

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References

- Adebowale Jeremy Adetayo, Augustine I Enamudu, Folashade Munirat Lawal, and Abiodun Olusegun Odunewu. 2024. From text to video with AI: the rise and potential of Sora in education and libraries. Library hi tech news (March 2024), 1–5. https://doi.org/10.1108/lhtn-02-2024-0028
- [2] Jorge Agnese, Jonathan Herrera, Haicheng Tao, and Xingquan Zhu. 2020. A survey and taxonomy of adversarial neural networks for text-to-image synthesis. Wiley interdisciplinary reviews. Data mining and knowledge discovery 10, 4 (July 2020), 1–26. https://doi.org/10.1002/widm.1345
- [3] Kashif Ahmad, Waleed Iqbal, Ammar El-Hassan, Junaid Qadir, Driss Benhaddou, Moussa Ayyash, and Ala Al-Fuqaha. 2024. Data-driven artificial intelligence in education: A comprehensive review. IEEE transactions on learning technologies 17 (2024), 12–31. https://doi.org/10.1109/tlt.2023.3314610
- [4] Patrick Adriel Aure and Oriana Cuenca. 2024. Fostering social-emotional learning through human-centered use of generative AI in business research education: an insider case study. *Journal of research in innovative teaching & learning* 17, 2 (Aug. 2024), 168–181. https://doi.org/10.1108/jrit-03-2024-0076
- [5] Zied Bahroun, Chiraz Anane, Vian Ahmed, and Andrew Zacca. 2023. Transforming education: A comprehensive review of generative artificial intelligence in educational settings through bibliometric and content analysis. Sustainability 15, 17 (Aug. 2023), 12983. https://doi.org/10.3390/su151712983
- [6] Rishi Bommasani, Drew A Hudson, Ehsan Adeli, Russ Altman, Simran Arora, and ... 2021. On the opportunities and risks of foundation models. arXiv (Aug. 2021). arXiv:2108.07258 [cs.LG]
- [7] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology.
 Qualitative research in psychology 3, 2 (Jan. 2006), 77–101. https://doi.org/10. 1191/1478088706qp063oa
- [8] Ricardo J G B Campello, Davoud Moulavi, and Joerg Sander. 2013. Density-Based Clustering Based on Hierarchical Density Estimates. In Advances in Knowledge Discovery and Data Mining. Springer Berlin Heidelberg, 160–172. https://doi. org/10.1007/978-3-642-37456-2 14
- [9] Rolando Chacón, Camilo Vieira, and Homero Murzi. 2023. Eliciting student understanding in structural engineering classrooms using text-to-image generative models. In 2023 IEEE Frontiers in Education Conference (FIE), Vol. 32. IEEE, 1–5. https://doi.org/10.1109/fie58773.2023.10343373
- [10] Ke Chen, Yusong Wu, Haohe Liu, Marianna Nezhurina, Taylor Berg-Kirkpatrick, and Shlomo Dubnov. 2024. MusicLDM: Enhancing novelty in text-to-music generation using beat-synchronous mixup strategies. In ICASSP 2024 2024 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Vol. 33. IEEE, 1206-1210. https://doi.org/10.1109/icassp48485.2024.10447265
- [11] Liuxin Chen, Amir Tophel, Umidu Hettiyadura, and Jayantha Kodikara. 2024. An investigation into the utility of large language models in geotechnical education and problem solving. Geotechnics 4, 2 (May 2024), 470–498. https://doi.org/10. 3390/geotechnics4020026

- [12] Xu Chen and Di Wu. 2024. Automatic generation of multimedia teaching materials based on generative AI: Taking tang poetry as an example. IEEE transactions on learning technologies 17 (2024), 1353–1366. https://doi.org/10.1109/tlt.2024. 3378279
- [13] Thomas K F Chiu. 2024. Future research recommendations for transforming higher education with generative AI. Computers and Education: Artificial Intelligence 6, 100197 (June 2024), 100197. https://doi.org/10.1016/j.caeai.2023.100197
- [14] Thomas K F Chiu, Zubair Ahmad, Murod Ismailov, and Ismaila Temitayo Sanusi. 2024. What are artificial intelligence literacy and competency? A comprehensive framework to support them. Computers and Education Open 6, 100171 (June 2024), 100171. https://doi.org/10.1016/j.caeo.2024.100171
- [15] Thomas K F Chiu, Qi Xia, Xinyan Zhou, Ching Sing Chai, and Miaoting Cheng. 2023. Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. Computers and Education: Artificial Intelligence 4 (Jan. 2023), 100118. https://doi.org/10.1016/j. caeai.2022.100118
- [16] Barbara Class and Colin De la Higuera. 2024. From disposable education to acting in the world as a human in the time of AI. Journal of Ethics in Higher Education 4 (July 2024), 231–244. https://doi.org/10.26034/fr.jehe.2024.5973
- [17] Katherine M Collins, Albert Q Jiang, Simon Frieder, Lionel Wong, Miri Zilka, Umang Bhatt, Thomas Lukasiewicz, Yuhuai Wu, Joshua B Tenenbaum, William Hart, Timothy Gowers, Wenda Li, Adrian Weller, and Mateja Jamnik. 2024. Evaluating language models for mathematics through interactions. Proceedings of the National Academy of Sciences of the United States of America 121, 24 (June 2024), 1–11. https://doi.org/10.1073/pnas.2318124121
- [18] Cope and Bill Mary Kalantzis. 2019. Education 2.0: Artificial intelligence and the end of the test. Beijing International Review of Education 1, 2-3 (June 2019), 528–543. https://doi.org/10.1163/25902539-00102009
- [19] Helen Crompton and Diane Burke. 2023. Artificial intelligence in higher education: the state of the field. *International journal of educational technology in higher education* 20, 1 (April 2023), 1–22. https://doi.org/10.1186/s41239-023-00392-8
- [20] Helen Crompton, Mildred V Jones, and Diane Burke. 2024. Affordances and challenges of artificial intelligence in K-12 education: a systematic review. *Journal* of research on technology in education 56, 3 (May 2024), 248–268. https://doi.org/ 10.1080/15391523.2022.2121344
- [21] David Wei Dai, Shungo Suzuki, and Guanliang Chen. 2024. Generative AI for professional communication training in intercultural contexts: where are we now and where are we heading? Applied linguistics review (July 2024), 1–12. https://doi.org/10.1515/applirev-2024-0184
- [22] K H Davis, R Biddulph, and S Balashek. 1952. Automatic recognition of spoken digits. The journal of the Acoustical Society of America 24, 6 (Nov. 1952), 637–642. https://doi.org/10.1121/1.1906946
- [23] Amy Deschenes and Meg McMahon. 2024. A survey on student use of generative AI chatbots for academic research. Evidence based library and information practice 19, 2 (June 2024), 2–22. https://doi.org/10.18438/eblip30512
- [24] Shayan Doroudi. 2022. The intertwined histories of artificial intelligence and education. *International journal of artificial intelligence in education* 33 (Oct. 2022), 885—928. https://doi.org/10.1007/s40593-022-00313-2
- [25] Jacob D Durrant. 2022. Prot2Prot: a deep learning model for rapid, photorealistic macromolecular visualization. Journal of computer-aided molecular design 36, 9 (Sept. 2022), 677–686. https://doi.org/10.1007/s10822-022-00471-4
- [26] Roman Egger and Joanne Yu. 2022. A Topic Modeling Comparison Between LDA, NMF, Top2Vec, and BERTopic to Demystify Twitter Posts. Frontiers in sociology 7 (May 2022), 886498. https://doi.org/10.3389/fsoc.2022.886498
- [27] Bingwen Eugene Fan, Minyang Chow, and Stefan Winkler. 2023. Artificial intelligence-generated facial images for medical education. *Medical science edu*cator 34, 1 (Nov. 2023), 5–7. https://doi.org/10.1007/s40670-023-01942-5
- [28] Effat Farhana, Souvika Sarkar, Ralph Knipper, Indrani Dey, Hari Narayanan, Sadhana Puntambekar, and Santu Karmaker. 2024. SimPal: Towards a metaconversational framework to understand teacher's instructional goals for K-12 physics. In Proceedings of the Eleventh ACM Conference on Learning @ Scale, Vol. 35. ACM, New York, NY, USA, 461–465. https://doi.org/10.1145/3657604.3664695
- [29] Johanna Fleckenstein, Jennifer Meyer, Thorben Jansen, Stefan D Keller, Olaf Köller, and Jens Möller. 2024. Do teachers spot AI? Evaluating the detectability of AI-generated texts among student essays. Computers and Education: Artificial Intelligence 6, 100209 (June 2024), 100209. https://doi.org/10.1016/j.caeai.2024. 100209
- [30] Rujun Gao, Hillary E Merzdorf, Saira Anwar, M Cynthia Hipwell, and Arun R Srinivasa. 2024. Automatic assessment of text-based responses in post-secondary education: A systematic review. Computers and Education: Artificial Intelligence 6, 100206 (June 2024), 100206. https://doi.org/10.1016/j.caeai.2024.100206
- [31] Puna Ram Ghimire, Bharat Prasad Neupane, and Niroj Dahal. 2024. Generative AI and AI tools in English language teaching and learning: An exploratory research. English Language Teaching Perspectives 9, 1-2 (Aug. 2024), 30–40. https://doi.org/10.3126/eltp.v9i1-2.68716
- [32] Maarten Grootendorst. 2022. BERTopic: Neural topic modeling with a class-based TF-IDF procedure. arXiv (2022), 1–10. https://doi.org/10.48550/arXiv.2203.05794

Table 2: Topics, representations, and example articles

#	N	Topic	Representation	Example article
1	654	LLMs in medical education	medical patient clinical chatgpt questions responses llms health accuracy healthcare potential care education models information ai medicine large performance language study methods gpt4 results bard using data nursing	[72]
2	546	Text-to-speech for learning support	speech texttospeech reading students audio text learning technology voice disabilities music people blind visually impaired using software language recognition english comprehension accessibility assistive application study read	[94]
3	249	GenAI in computing education	programming code students llms software models computer introductory tools computing learning course language feedback courses science chatgpt exercises cs1 ai generative problems help education explanations	[69]
4	160	Writing support and feedback	writing students feedback ai generative tools study essays chatgpt english language literacy essay teachers skills research intelligence artificial academic learners llms creative tool texts results business model	[48]
5	139	Ethical and security challenges	ai intelligence artificial generative marketing research ethical chatgpt technologies data potential systems development scientific new human digital technology education risks language article models large llms future security challenges	[99]
6	129	Educational chatbots	chatgpt chatbots learning students education information ai educational generative user data srl intelligence support artificial knowledge research teachers users college tools teaching academic	[34]
7	92	Tools for content and learning design	generative learning ai education educational content genai teachers tools design lesson intelligence personalized teaching artificial students instructional learners study creation materials potential collaborative humanmachine educators classroom experience future create paper	[68]
8	74	Feedback and personalized responses	learning feedback language models llms large knowledge educational model processing systems students natural prompt personalized responses nlp generation peerfeedback llm education instructors engineering content using understanding ai adaptive paper student	[39]
9	63	Acceptance and adoption	acceptance factors expectancy technology intention students influence use chatgpt study perceived theory ai adoption behavioral significantly usage tools equation satisfaction tam structural effort model unified research generative intentions education genai	[76]
10	54	GenAI in higher education	genai higher education learning teaching students gen change generative ai student artt educational chatgpt course experiences adult use research tools university collection study approach technologies impact assessment adoption leadership literacy	[13]
11	54	Assessment and academic integrity	assessment assessments generative authentic ai learning higher students academic gai tools evaluative integrity student academics education artificial intelligence work exams traditional judgement educational chatgpt formative genai new online practices concerns	[52]
12	53	LLMs in education	education learning llms language large models educational ai chatgpt potential intelligence artificial higher challenges generative teaching educators clos ml paper students human article teachers opportunities tools impact particularly tool strategies	[66]
13	51	Automated grading and performance evaluation	answer grading models scoring performance model answers assessment item automated large questions student evaluation llms dataset language responses items accuracy gpt4 educational similarity test section short evaluating math formative	[30]
14	49	Ethical implications and policies	ethical ai generative education ethics issues educational intelligence chapter higher use artificial learning policy challenges privacy educators concerns technologies students risks tools emerging implications technology teaching humanities human potential academic	[61]
15	48	Detecting AI-generated text	detection aigenerated academic text essays texts integrity detectors plagiarism ai writing humanwritten generated articles content detect use student models written tools human work chatgpt accuracy language students distinguishing airephrased educators	[29]
16	46	Creativity, art, and design	magic art creative ai creativity generative design digital students animation tools images education artistic artificial intelligence divergent thinking study human religious icons media explore texttoimage article create hybrid class new	[87]
17	46	Chatbots for language learning	language chatgpt chatbots learning korean large speaking research teachers chinese chatbot education teaching efl vocabulary based models using oral study interviews students learners potential foreign ai use coole pitanja artificial	[98]

#	N	Topic	Representation	Example article
18	43	Sentiments toward AI in social media	social chatgpt resilience chatbot media study emotions educational negative chatbots sentiment childrens analysis education users use coaching trust higher version learning autonomy research positive online intelligence emotional ai findings implications	[53]
19	43	Impact on academic integrity	integrity academic higher ai plagiarism universities policy genai policies students use institutions ethical education misconduct tools intelligence student artificial institutional generative research heis study staff concerns regarding issues analysis framework	[45]
20	42	AI literacy	ai literacy research generative students study gai higher education academic tools perceptions artificial findings intelligence use participants teachers adoption competence k12 using usage knowledge professionals approach genai ais competencies technology	[14]
21	37	Translation and intercultural skills	translation foreign language teaching issue english special artificial interpreting intelligence papers skills research studies communication competence	[21]
22	36	Automated questions generation	question questions generation mcqs evaluation generated language conference model qg t5 educational quality learning wang kcs prompting models generate aqg large generating automatic knowledge teachers natural using llms qa transformer	[33]
23	36	Tutoring systems	tutoring tutor tutors learning dialogue da large students bot models systems student collaborative classifier language instructor llm knowledge chatbot classifiers feedback architecture design support model teachable intelligent dialogues virtual asr	[47]
24	35	Language teaching	genai language teaching tools english study teachers chatgpt students learning qualitative ai generative attitudes use findings educators efl gai education enhance challenges academic ilte integration quantitative analysis interviews research l2	[59]
25	34	Chemistry education	chemistry chemical engineering students mechanistic reasoning scientific responses problems chatbots valence prompts assignments science chatgpt writing llms molecule simulation generative ai molecular learning artificial	[82]
26	34	Text-to-image for visual design and creativity	designers fashion ideation creative process creativity solutions product tools visual think- ing texttoimage stimuli images generative ideas analogies collaborative phase search students sustainable study technology engineering	[41]
27	31	Mathematical explanations and problem-solving	mathematical mathematics explanations problems llms models tutoring word feedback language tasks gpt4 large llama answers error model problemsolving learning generated stories lesson generating plans task	[17]
28	29	Teacher education and professional development	teachers gai educators ai teaching tools study training generative practices education mathematics technological preservice participants intelligence learning projectbased artificial research chatgpt support assessment preparedness professional faculty development	[79]
29	26	Engineering education	engineering generative ai students tools chatgpt mechanical education circuits peer team teams paper design electric individual learning tool performance civil feedback practices hackathon research career questions study	[96]
30	25	Tools for library and research	libraries information librarians literacy services academic archival research data faculty entrepreneurs university ai technology students generative media xr gis adoption staff digital tools new legacy justice community	[23]
31	25	Physics education, problem-solving, and simulations	physics llms language problems large solving models tasks questions model solve problemsolving learning prompting gpt4 students different llm chatgpt instructional generate answers physical simulations research school	[71]
32	24	Business and entrepreneurial education	business ai entrepreneurship genai generative education intelligence artificial higher fu- ture research students case opportunities impact learning potential study entrepreneurial competencies academic service course implications informed teaching	[4]
33	21	Philosophy of education in the age of AI	intelligence human generative ai cognitive artificial connectionist knowledge philosophical education paradox epistemology perils tension biological epistemic argues stiegler philebus technologies embodied cognition nature virtue educational learning	[16]
34	20	Geoscience education	visual models image capabilities gis geotechnical problems programming multimodal model gpt4 large spatial reasoning images vision diagram geoscience features exam weather science llms challenges solving earth gpt4s finegrained	[11]
35	20	Critical perspective on chatbots	higher ai chatbots students education critical chatgpt research supervision supervisors practices tools supervisory artificial postgraduate academic chatbot concerns integrity impact generative intelligence need claims ethical teaching faculty study	[40]

#	N	Topic	Representation	Example article
36	20	Sentiment and emotion analysis	sentiment emotion student data course annotations classification analysis feedback courses labels models language emotions crowdsourced processing bert text large natural performance comments sentiments stage dataset approach labeled	[65]
37	20	Detecting AI-generated code submissions	code submissions style detectors detection anomaly perplexity anomalies assignments plagiarism cheating models programming detect similarity solutions work large detecting contractors student bounds aigenerated codebert classifier generated tests samples problem constants	[64]
38	17	GenAI and serious games	games escape gamebased rooms plans educational designers framework puzzles design actions players learning generation development levels reactions chemical process procedural content atoms educators	[84]

- [33] Ching Nam Hang, Chee Wei Tan, and Pei-Duo Yu. 2024. MCQGen: A large language model-driven MCQ generator for personalized learning. IEEE access: practical innovations, open solutions 12 (2024), 102261–102273. https://doi.org/ 10.1109/access.2024.3420709
- [34] Michael A Hedderich, Natalie N Bazarova, Wenting Zou, Ryun Shim, Xinda Ma, and Qian Yang. 2024. A piece of theatre: Investigating how teachers design LLM chatbots to assist adolescent cyberbullying education. In Proceedings of the CHI Conference on Human Factors in Computing Systems, Vol. 5. ACM, New York, NY, USA, 1–17. https://doi.org/10.1145/3613904.3642379
- [35] Ville Heilala, Päivikki Jääskelä, Mirka Saarela, Anna-Stina Kuula, Anne Eskola, and Tommi Kärkkäinen. 2022. "Sitting at the Stern and Holding the Rudder": Teachers' Reflections on Action in Higher Education Based on Student Agency Analytics. In Digital Teaching and Learning in Higher Education: Developing and Disseminating Skills for Blended Learning, Leonid Chechurin (Ed.). Palgrave Macmillan, Cham, 71–91. https://doi.org/10.1007/978-3-031-00801-6_4
- [36] Ville Heilala, Päivikki Jääskelä, Mirka Saarela, and Tommi Kärkkäinen. 2023. Adapting teaching and learning in higher education using explainable student agency analytics. In Principles and Applications of Adaptive Artificial Intelligence. IGI Global, 20–51. https://doi.org/10.4018/979-8-3693-0230-9.ch002
- [37] Niklas Humble and Peter Mozelius. 2022. The threat, hype, and promise of artificial intelligence in education. Discover Artificial Intelligence 2, 1 (Nov. 2022), 1–13. https://doi.org/10.1007/s44163-022-00039-z
- [38] W John Hutchins. 2004. The Georgetown-IBM experiment demonstrated in January 1954. In Lecture Notes in Computer Science. Springer Berlin Heidelberg, Berlin, Heidelberg, 102–114. https://doi.org/10.1007/978-3-540-30194-3_12
- [39] Stephen Hutt, Allison DePiro, Joann Wang, Sam Rhodes, Ryan S Baker, Grayson Hieb, Sheela Sethuraman, Jaclyn Ocumpaugh, and Caitlin Mills. 2024. Feedback on feedback: Comparing classic natural language processing and generative AI to evaluate peer feedback. In Proceedings of the 14th Learning Analytics and Knowledge Conference. ACM, New York, NY, USA, 55–65. https://doi.org/10.1145/ 3636555.3636850
- [40] Lasse X Jensen, Alexandra Buhl, Anjali Sharma, and Margaret Bearman. 2024. Generative AI and higher education: a review of claims from the first months of ChatGPT. Higher education (July 2024), 1–17. https://doi.org/10.1007/s10734-024-01265-3
- [41] Dawool Jung and Sungeun Suh. 2024. Enhancing soft skills through generative AI in sustainable fashion textile design education. Sustainability 16, 16 (Aug. 2024), 6973. https://doi.org/10.3390/su16166973
- [42] Navroz Kaur Kahlon and Williamjeet Singh. 2023. Machine translation from text to sign language: a systematic review. *Universal access in the information society* 22, 1 (March 2023), 1–35. https://doi.org/10.1007/s10209-021-00823-1
- [43] Maria Kambouri, Helen Simon, and Greg Brooks. 2023. Using speech-to-text technology to empower young writers with special educational needs. Research in developmental disabilities 135, 104466 (April 2023), 104466. https://doi.org/10. 1016/j.ridd.2023.104466
- [44] Dennis H Klatt. 1987. Review of text-to-speech conversion for English. The journal of the Acoustical Society of America 82, 3 (Sept. 1987), 737–793. https://doi.org/10.1121/1.395275
- [45] Daniel Lee, Matthew Arnold, Amit Srivastava, Katrina Plastow, Peter Strelan, Florian Ploeckl, Dimitra Lekkas, and Edward Palmer. 2024. The impact of generative AI on higher education learning and teaching: A study of educators' perspectives. Computers and Education: Artificial Intelligence 6, 100221 (June 2024), 100221. https://doi.org/10.1016/j.caeai.2024.100221
- [46] Sarah Levine, Hsiaolin Hsieh, Emily Southerton, and Rebecca Silverman. 2023. How high school students used speech-to-text as a composition tool. Computers and composition 68, 102775 (June 2023), 102775. https://doi.org/10.1016/j.compcom.2023.102775

- [47] Jionghao Lin, Zifei Han, Danielle R Thomas, Ashish Gurung, Shivang Gupta, Vincent Aleven, and Kenneth R Koedinger. 2024. How can I get it right? Using GPT to rephrase incorrect trainee responses. *International journal of artificial intelligence in education* (July 2024), 1–27. https://doi.org/10.1007/s40593-024-00408-v
- [48] Meilu Liu, Lawrence Jun Zhang, and Christine Biebricher. 2024. Investigating students' cognitive processes in generative AI-assisted digital multimodal composing and traditional writing. Computers & education 211, 104977 (April 2024), 104977. https://doi.org/10.1016/j.compedu.2023.104977
- [49] Yi-Lin Elim Liu and Yueh-Min Huang. 2024. Exploring the perceptions and continuance intention of AI-based text-to-image technology in supporting design ideation. *International journal of human-computer interaction* (Feb. 2024), 1–13. https://doi.org/10.1080/10447318.2024.2311975
- [50] Kyle Lo, Lucy Lu Wang, Mark Neumann, Rodney Kinney, and Daniel Weld. 2020. S2ORC: The Semantic Scholar Open Research Corpus. In Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics. Association for Computational Linguistics, Online, 4969–4983. https://doi.org/10.18653/v1/2020. acl-main.447
- [51] Ming Y Lu, Bowen Chen, Drew F K Williamson, Richard J Chen, Melissa Zhao, Aaron K Chow, Kenji Ikemura, Ahrong Kim, Dimitra Pouli, Ankush Patel, Amr Soliman, Chengkuan Chen, Tong Ding, Judy J Wang, Georg Gerber, Ivy Liang, Long Phi Le, Anil V Parwani, Luca L Weishaupt, and Faisal Mahmood. 2024. A multimodal generative AI copilot for human pathology. *Nature* 634 (June 2024), 466–473. https://doi.org/10.1038/s41586-024-07618-3
- [52] Jiahui Luo (Jess). 2024. A critical review of GenAI policies in higher education assessment: a call to reconsider the "originality" of students' work. Assessment and evaluation in higher education 49, 5 (July 2024), 651–664. https://doi.org/10. 1080/02602938.2024.2309963
- [53] Yoseph Mamo, Helen Crompton, Diane Burke, and Christine Nickel. 2024. Higher education faculty perceptions of ChatGPT and the influencing factors: A sentiment analysis of X. TechTrends: for leaders in education & training 68, 3 (May 2024), 520–534. https://doi.org/10.1007/s11528-024-00954-1
- [54] Marianne Engen Matre and David Lansing Cameron. 2024. A scoping review on the use of speech-to-text technology for adolescents with learning difficulties in secondary education. *Disability and rehabilitation. Assistive technology* 19, 3 (April 2024), 1103–1116. https://doi.org/10.1080/17483107.2022.2149865
- [55] Ugochukwu Okwudili Matthew, Jazuli Sanusi Kazaure, Charles Chukwue-buka Ndukwu, Godwin Nse Ebong, Andrew Chinonso Nwanakwaugwu, and Ubochi Chibueze Nwamouh. 2024. Artificial Intelligence Educational Pedagogy Development: ICT Pedagogy Development for Education 5.0. In Advances in Business Information Systems and Analytics. IGI Global, 65–93. https://doi.org/10.4018/979-8-3693-2314-4.ch003
- [56] Leland McInnes, John Healy, Nathaniel Saul, and Lukas Großberger. 2018. UMAP: Uniform Manifold Approximation and Projection. Journal of open source software 3, 29 (Sept. 2018), 861. https://doi.org/10.21105/joss.00861
- [57] Ali A Mohamed and Brandon Lucke-Wold. 2024. Text-to-video generative artificial intelligence: sora in neurosurgery. *Neurosurgical review* 47, 1 (June 2024), 272. https://doi.org/10.1007/s10143-024-02514-w
- [58] Pitshou Moleka. 2023. Exploring the role of artificial intelligence in education 6.0: Enhancing personalized learning and adaptive pedagogy. *Preprints* (Sept. 2023), 1–8. https://doi.org/10.20944/preprints202309.0562.v1
- [59] Benjamin Luke Moorhouse and Lucas Kohnke. 2024. The effects of generative AI on initial language teacher education: The perceptions of teacher educators. System 122, 103290 (June 2024), 103290. https://doi.org/10.1016/j.system.2024. 103290
- [60] Davoud Moulavi, Pablo A Jaskowiak, Ricardo J G B Campello, Arthur Zimek, and Jörg Sander. 2014. Density-based clustering validation. In Proceedings of the 2014 SIAM International Conference on Data Mining. Society for Industrial

- and Applied Mathematics, Philadelphia, PA, 839–847. https://doi.org/10.1137/1. 9781611973440.96
- [61] Emmanuel K Nartey. 2024. Guiding principles of generative AI for employability and learning in UK universities. Cogent education 11, 1 (Dec. 2024), 1–27. https://doi.org/10.1080/2331186x.2024.2357898
- [62] Selena Nemorin, Andreas Vlachidis, Hayford M Ayerakwa, and Panagiotis Andriotis. 2023. AI hyped? A horizon scan of discourse on artificial intelligence in education (AIED) and development. *Learning, media and technology* 48, 1 (Jan. 2023), 38–51. https://doi.org/10.1080/17439884.2022.2095568
- [63] Oluwole Remi Omotayo. 1983. A microcomputer-based reading aid for blind students. IEEE transactions on education 26, 4 (Nov. 1983), 156-161. https://doi.org/10.1109/te.1983.4321634
- [64] Wei Hung Pan, Ming Jie Chok, Jonathan Leong Shan Wong, Yung Xin Shin, Yeong Shian Poon, Zhou Yang, Chun Yong Chong, David Lo, and Mei Kuan Lim. 2024. Assessing AI detectors in identifying AI-generated code: Implications for education. In Proceedings of the 46th International Conference on Software Engineering: Software Engineering Education and Training. ACM, New York, NY, USA, 1–11. https://doi.org/10.1145/3639474.3640068
- [65] Michael J Parker, Caitlin Anderson, Claire Stone, and Yearim Oh. 2024. A large language model approach to educational survey feedback analysis. *International journal of artificial intelligence in education* (June 2024), 1–38. https://doi.org/10.1007/s40593-024-00414-0
- [66] Iris Cristina Peláez-Sánchez, Davis Velarde-Camaqui, and Leonardo David Glasserman-Morales. 2024. The impact of large language models on higher education: exploring the connection between AI and Education 4.0. Frontiers in Education 9 (2024), 1–21. https://doi.org/10.3389/feduc.2024.1392091
- [67] Jesus Perez-Martin, Benjamin Bustos, Silvio Jamil F Guimarães, Ivan Sipiran, Jorge Pérez, and Grethel Coello Said. 2022. A comprehensive review of the video-to-text problem. Artificial intelligence review 55, 5 (June 2022), 4165–4239. https://doi.org/10.1007/s10462-021-10104-1
- [68] Wardell Powell and Steven Courchesne. 2024. Opportunities and risks involved in using ChatGPT to create first grade science lesson plans. PloS one 19, 6 (June 2024), e0305337. https://doi.org/10.1371/journal.pone.0305337
- [69] James Prather, Brent N Reeves, Juho Leinonen, Stephen MacNeil, Arisoa S Randrianasolo, Brett A Becker, Bailey Kimmel, Jared Wright, and Ben Briggs. 2024. The widening gap: The benefits and harms of generative AI for novice programmers. In Proceedings of the 2024 ACM Conference on International Computing Education Research Volume 1, Vol. 6. ACM, New York, NY, USA, 469–486. https://doi.org/10.1145/3632620.3671116
- [70] Raghu Raman, Debidutta Pattnaik, Laurie Hughes, and Prema Nedungadi. 2024. Unveiling the dynamics of AI applications: A review of reviews using scientometrics and BERTopic modeling. *Journal of innovation & knowledge* 9, 3 (July 2024), 100517. https://doi.org/10.1016/j.jik.2024.100517
- [71] Andrii V Riabko and Tetiana A Vakaliuk. 2024. Physics on autopilot: exploring the use of an AI assistant for independent problem-solving practice. *Educational Technology Quarterly* 2024, 1 (March 2024), 56–75. https://doi.org/10.55056/etq. 671
- [72] Armaun D Rouhi, Yazid K Ghanem, Laman Yolchieva, Zena Saleh, Hansa Joshi, Matthew C Moccia, Alejandro Suarez-Pierre, and Jason J Han. 2024. Can artificial intelligence improve the readability of patient education materials on aortic stenosis? A pilot study. Cardiology and therapy 13, 1 (March 2024), 137–147. https://doi.org/10.1007/s40119-023-00347-0
- [73] Mohammed Ahmed Sadeq, Reem Mohamed Farouk Ghorab, Mohamed Hady Ashry, Ahmed Mohamed Abozaid, Haneen A Banihani, Moustafa Salem, Mohammed Tawfiq Abu Aisheh, Saad Abuzahra, Marina Ramzy Mourid, Mohamad Monif Assker, Mohammed Ayyad, and Mostafa Hossam El Din Moawad. 2024. AI chatbots show promise but limitations on UK medical exam questions: a comparative performance study. Scientific reports 14, 1 (Aug. 2024), 1–11. https://doi.org/10.1038/s41598-024-68996-2
- [74] Sam Sedaghat. 2023. Success through simplicity: What other artificial intelligence applications in medicine should learn from history and ChatGPT. *Annals of biomedical engineering* 51, 12 (Dec. 2023), 2657–2658. https://doi.org/10.1007/ s10439-023-03287-x
- [75] Mika Setälä, Ville Heilala, Pieta Sikström, and Tommi Kärkkäinen. 2025. The Use of Generative Artificial Intelligence for Upper Secondary Mathematics Education Through the Lens of Technology Acceptance. In *The 40th ACM/SIGAPP Symposium on Applied Computing (SAC '25)*. ACM, New York, NY, USA. https: //doi.org/10.1145/3672608.3707817
- [76] Muhammad Farrukh Shahzad, Shuo Xu, and Iqra Javed. 2024. ChatGPT awareness, acceptance, and adoption in higher education: the role of trust as a cornerstone. International journal of educational technology in higher education 21, 1 (July 2024), 1–23. https://doi.org/10.1186/s41239-024-00478-x
- [77] Pieta Sikström, Chiara Valentini, Anu Sivunen, and Tommi Kärkkäinen. 2022. How pedagogical agents communicate with students: A two-phase systematic review. Computers & education 188 (Oct. 2022), 104564. https://doi.org/10.1016/j. compedu.2022.104564
- [78] Tolulope Sulaimon and John Schaefer. 2023. The impact of text-to-speech on reading comprehension of students with learning disabilities in an urban school.

- $\label{trends:for leaders in education \& training 67, 2 (March 2023), 376-383. \\ https://doi.org/10.1007/s11528-022-00800-2$
- [79] Mei Tan and Hari Subramonyam. 2024. More than model documentation: Uncovering teachers' bespoke information needs for informed classroom integration of ChatGPT. In Proceedings of the CHI Conference on Human Factors in Computing Systems, Vol. 105. ACM, New York, NY, USA, 1–19. https://doi.org/10.1145/3613904.3642592
- [80] Samson Tan. 2023. Harnessing artificial intelligence for innovation in education. In Learning Intelligence: Innovative and Digital Transformative Learning Strategies. Springer Nature Singapore, Singapore, 335–363. https://doi.org/10.1007/978-981-19-9201-8_8
- [81] Sebastián Tapia-Mandiola and Roberto Araya. 2024. From play to understanding: Large language models in logic and spatial reasoning coloring activities for children. AI 5, 4 (Oct. 2024), 1870–1892. https://doi.org/10.3390/ai5040093
- [82] Sebastian Tassoti. 2024. Assessment of students use of generative artificial intelligence: Prompting strategies and prompt engineering in chemistry education. *Journal of chemical education* 101, 6 (June 2024), 2475–2482. https://doi.org/10.1021/acs.jchemed.4c00212
- [83] Mike Thelwall. 2018. Dimensions: A competitor to Scopus and the Web of Science? Journal of informetrics 12, 2 (May 2018), 430–435. https://doi.org/10. 1016/j.joi.2018.03.006
- [84] Janne Tyni, Aatu Turunen, Juho Kahila, Roman Bednarik, and Matti Tedre. 2024. Can ChatGPT Match the Experts? A Feedback Comparison for Serious Game Development. *International Journal of Serious Games* 11, 2 (June 2024), 87–106. https://doi.org/10.17083/ijsg.v11i2.744
- [85] UNESCO. 2019. Beijing Consensus on Artificial Intelligence and Education. https://unesdoc.unesco.org/ark:/48223/pf0000368303
- [86] UNESCO. 2023. Guidance for generative AI in education and research. https://doi.org/10.54675/ewzm9535
- [87] Henriikka Vartiainen, Matti Tedre, and Ilkka Jormanainen. 2023. Co-creating digital art with generative AI in K-9 education: Socio-material insights. International journal of education through art 19, 3 (Sept. 2023), 405–423. https://doi.org/10.1386/eta_00143_1
- [88] Varshini Venkatesh, Vaishnavi Venkatesh, and Viraj Kumar. 2023. Evaluating copilot on CS1 code writing problems with suppressed specifications. In Proceedings of the 16th Annual ACM India Compute Conference. ACM, New York, NY, USA, 104–107. https://doi.org/10.1145/3627217.3627235
- [89] Pieter Verdegem. 2022. Dismantling AI capitalism: the commons as an alternative to the power concentration of Big Tech. AI & society (April 2022), 1–11. https://doi.org/10.1007/s00146-022-01437-8
- [90] Manoj Kumar Verma and Mayank Yuvaraj. 2023. What's up in WhatsApp research: a comprehensive analysis of 12,947 papers indexed in Dimensions.ai. Library hi tech (Dec. 2023), 1–36. https://doi.org/10.1108/lht-11-2023-0525
- [91] Catalin Vrabie. 2023. Education 3.0 AI and gamification tools for increasing student engagement and knowledge retention. In *Lecture Notes in Business Information Processing*. Springer Nature Switzerland, Cham, 74–87. https://doi. org/10.1007/978-3-031-43590-4_5
- [92] Shan Wang, Fang Wang, Zhen Zhu, Jingxuan Wang, Tam Tran, and Zhao Du. 2024. Artificial intelligence in education: A systematic literature review. Expert systems with applications 252, 124167 (Oct. 2024), 124167. https://doi.org/10. 1016/j.eswa.2024.124167
- [93] Zhongyi Wang, Jing Chen, Jiangping Chen, and Haihua Chen. 2024. Identifying interdisciplinary topics and their evolution based on BERTopic. Scientometrics 129 (July 2024), 7359–7384. Issue 11. https://doi.org/10.1007/s11192-023-04776-5
- [94] Oshani Weerakoon, Ville Leppänen, and Tuomas Mäkilä. 2024. Enhancing pedagogy with generative AI: Video production from course descriptions. In Proceedings of the International Conference on Computer Systems and Technologies 2024. ACM, New York, NY, USA, 249–255. https://doi.org/10.1145/3674912.3674922
- [95] Zhenyu Xu and Victor S Sheng. 2024. Detecting AI-generated code assignments using perplexity of large language models. Proceedings of the ... AAAI Conference on Artificial Intelligence. AAAI Conference on Artificial Intelligence 38, 21 (March 2024), 23155–23162. https://doi.org/10.1609/aaai.v38i21.30361
- [96] Kumar Yelamarthi, Raju Dandu, Mohan Rao, Venkata Prasanth Yanambaka, and Satish Mahajan. 2024. Exploring the potential of generative AI in shaping engineering education: Opportunities and challenges. *Journal of Engineering Educa*tion Transformations 37, IS2 (Jan. 2024), 439–445. https://doi.org/10.16920/jeet/ 2024/v37is2/24072
- [97] Abdullahi Yusuf, Nasrin Pervin, Marcos Román-González, and Norah Md Noor. 2024. Generative AI in education and research: A systematic mapping review. Review of education 12, 2 (Aug. 2024), 1–36. https://doi.org/10.1002/rev3.3489
- [98] Zhihui Zhang and Xiaomeng Huang. 2024. The impact of chatbots based on large language models on second language vocabulary acquisition. *Heliyon* 10, 3 (Feb. 2024), e25370. https://doi.org/10.1016/j.heliyon.2024.e25370
- [99] Niina Zuber and Jan Gogoll. 2024. Vox populi, Vox ChatGPT: Large language models, education and democracy. *Philosophies* 9, 1 (Jan. 2024), 13. https://doi.org/10.3390/philosophies9010013