O6 - The Impact of Artificial Intelligence on Cognitive Load in Computing Education

Short paper

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Short paper: 1 Introduction

The rapid development of Generative AI (GAI) makes an impact in many fields of our society, and for higher education this is a fact that must be addressed. Research has reported on GAI creating new challenges, and GAI as a catalyst for a transformation of higher education (Chiu, 2024; Yusuf et al., 2024). According to Chiu (2024) the four most important educational domains to consider are learning, teaching, assessment and administration. This study had a focus on learning, and as pointed out by Choudhuri et al. (2024), there is a gap in the understanding of the potential and the pitfalls when using GAI in computing education. The aim of this paper is to explore the potential impact of AI technologies on cognitive load, relevant for computing education at higher education level. The research question to answer is:

What is the potential impact of AI technologies on cognitive load in computing education according to recent research?

2 Cognitive Load Theory

Cognitive Load Theory (CLT) was first developed by John Sweller and colleagues in the 1980s and has become one of the more influential theories in educational psychology (Schnotz & Kürschner, 2007). CLT describes the working memory resources that are involved in a learning task and divides the cognitive load that a learner can experience in intrinsic load, extraneous load, and germane load (Kirschner et al., 2018). Intrinsic and extraneous load are often considered to be the two main sources for cognitive load, dealing with the complexity of processed information (intrinsic) and the way that it is presented (extraneous) (Kirschner et al., 2018). While germane load covers the working memory resources used for dealing with new information to be processed, which is the intrinsic load (Kirschner et al., 2018).

Further, the theory often stresses the importance of learners' cognitive systems, and that instructions for learning needs to be adapted and designed after these (Schnotz & Kürschner, 2007). The theory has also been questioned, for example concerning its generalizability, and there is an ongoing debate on interpreting and transforming the theory (Schnotz & Kürschner, 2007). However, this study will not cover the criticism and debate concerning CLT, but use the definition outlined above.

3 Method

This study applied a scoping literature review approach for seeking available evidence in prior research (Munn et al., 2018) and identify potentials for future research and implications for practices (Tricco et al., 2016). A search was conducted in May of 2024 in databases Web of Science and Scopus that combined keywords “artificial intelligence” and “cognitive load” with “computing” or “programming” or “computer science”. The search identified 56 potentially relevant papers in Scopus and 8 in Web of Science. Papers were selected for inclusion based on the following criteria: published between 2019 and 2024, written in English, journal article or conference paper, relevant for the study’s aim and research question. After screening and removing of duplicates, 7 papers were chosen for inclusion in the study. The included papers were analyzed with thematic analysis, following the guidelines by Braun and Clarke (2006) for a thematic analysis.

4 Results

Through the thematic analysis 4 themes were identified which relates to the potential impact of AI technologies on cognitive load in computing education. These are “language learning assistance”, “intelligent support agents”, “intelligent virtual learning environments (VLE)”, and “game-based learning (GBL) strategies”. These themes, with connection to included papers, are depicted in Table 1 and further discussed in relation to Cognitive Load Theory in the next section.

5 Discussion

The theme of language learning assistance highlights that applying AI to auto-generate subtitles (Malakul & Park, 2023) and to provide speech recognition that is dynamic and assessment-based (Chen et al., 2022b) does not increase the cognitive load compared to alternative strategies for language learning in the studies. It should be important to understand this in relation to the complexity of the language content, since more complex content usually is more difficult to present and therefore increases the cognitive load. The results presented here are promising but should be investigated further.

The theme of intelligent support agents highlights that AI can be used for support in retrieving scientific articles (Cheng et al., 2022a), provide recommendations in everyday decision making (Oruç et al., 2022), and act as a conversational partner for end user developers (Asunis et al., 2021). All of the mentioned studies in this theme, discuss their designs in relation to having positive effects on cognitive load for the user. As with the previous theme, this should however be understood in relation to the complexity of information and the design of its presentation. Intelligent support agents do not reduce cognitive load automatically, it is dependent on the complexity of the information and how it is presented to the user or learner.

The last two themes, intelligent VLE and GBL strategies, differs from the previous two. Intelligent VLE highlight many of the positive aspects that it can have on students’ learning and collaboration but recognizes that there are challenges for technical cognitive load (Wei & Jia (2021). The cognitive load challenge of intelligent VLE should not be surprising given the complexity of the environments and future research could explore positive design for addressing extraneous cognitive load. A positive approach for this could be related to the theme of GBL strategies, which has been shown to enhance skills, knowledge and motivation related to computer science while also reducing

cognitive load (Ma et al., 2022).

6 Conclusion

The conclusion of this study is that the potential impact of AI technologies on cognitive load in computing education, based on included papers, shows promise. However, the authors of this paper would like to stress that reduced cognitive load will not simply happen by introducing AI. The complexity of content and design of its presentation, for example through user interaction, is still very important.

7 Limitations and future research

Concerning limitations of this study, the low number of included papers needs be addressed. Future research should widen the literature review by including more databases and identifying more relevant keywords to incorporate in the query string. This could potentially increase the number of identified relevant papers to be included. An alternative for increasing the number of included papers could also be to widen the time frame for inclusion from 5 years to 10 years, and to apply backward and forward searches on identified papers.

A small but interesting theme in the findings was GBL strategies, which could be explored further in future research. A study on GBL strategies could analyze educational games involving AI and computing education to identify which game design aspects reduce or increase the cognitive load?

Table 1. Identified themes and included papers.

	Language learning assistance	**Intelligent support agents**	**Intelligent virtual learning environments**	**Game-based learning strategies**
Malakul & Park (2023)	Auto-generated subtitles			
Cheng et al. (2022a)		Internet articles retrieval agent		
Chen et al. (2022b)	Dynamic speech recognition			
Ma et al. (2022)				GBL for effective learning
Oruç et al. (2022)		Decision support agent		
Asunis et al. (2021)		Conversational intelligent agent		
Wei & Jia (2021)			Challenges of VLE	

References

Asunis, L., Frau, V., Macis, R., Pireddu, C., & Spano, L. D. (2021, June). PAC-Bot: Writing text messages for developing point-and-click games. In *International Symposium on End User Development* (pp. 213-221). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-79840-6_15

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa
Cheng, Y. P., Cheng, S. C., & Huang, Y. M. (2022a). An internet articles retrieval agent combined with dynamic associative concept maps to implement online learning in an artificial intelligence course. *International Review of Research in Open and Distributed Learning, 23*(1), 63-81. https://doi.org/10.19173/irrodl.v22i4.5437
Chen, C. H., Koong, C. S., & Liao, C. (2022b). Influences of integrating dynamic assessment into a speech recognition learning design to support students' English speaking skills, learning anxiety and cognitive load. *Educational Technology & Society, 25*(1), 1-14. https://www.jstor.org/stable/48647026
Chiu, T. K. (2024). Future research recommendations for transforming higher education with generative AI. *Computers and Education: Artificial Intelligence*, *6*, 100197. https://doi.org/10.1016/j.caeai.2023.100197
Choudhuri, R., Liu, D., Steinmacher, I., Gerosa, M., & Sarma, A. (2024, April). How Far Are We? The Triumphs and Trials of Generative AI in Learning Software Engineering. In *Proceedings of the IEEE/ACM 46th International Conference on Software Engineering* (pp. 1-13). https://doi.org/10.1145/3597503.3639201
Kirschner, P. A., Sweller, J., Kirschner, F., & Zambrano R, J. (2018). From cognitive load theory to collaborative cognitive load theory. *International journal of computer-supported collaborative learning, 13*, 213-233. https://doi.org/10.1007/s11412-018-9277-y
Ma, J., Zhang, Y., Bin, H., Wang, K., Liu, J., & Gao, H. (2022, July). The Development of Students' Computational Thinking Practices in AI Course Using the Game-Based Learning: A Case Study. In *2022 International Symposium on Educational Technology (ISET)* (pp. 273-277). IEEE. https://doi.org/10.1109/ISET55194.2022.00065
Malakul, S., & Park, I. (2023). The effects of using an auto-subtitle system in educational videos to facilitate learning for secondary school students: learning comprehension, cognitive load, and satisfaction. *Smart Learning Environments, 10*(1), 4. https://doi.org/10.1186/s40561-023-00224-2
Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*(1), 143. https://doi.org/10.1186/s12874-018-0611-x
Oruç, S., Eren, P. E., & Koçyiğit, A. (2022). A constraint programming model for making recommendations in personal process management: A design science research approach. *Decision Support Systems, 152*, 113665. https://doi.org/10.1016/j.dss.2021.113665
Schnotz, W., & Kürschner, C. (2007). A reconsideration of cognitive load theory. *Educational psychology review, 19*, 469-508. https://doi.org/10.1007/s10648-007-9053-4
Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., Levac, D., Ng, C., Sharpe, J. P., Wilson, K., Kenny, M., Warren, R., Wilson, C., Stelfox, H. T., & Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology, 16*(1), 15. https://doi.org/10.1186/s12874-016-0116-4
Wei, X., & Jia, H. (2021, December). A Review of the Application of Artificial Intelligence in the Virtual Learning Environment. In *2021 Tenth International Conference of Educational Innovation through Technology (EITT)* (pp. 79-82). IEEE. https://doi.org/10.1109/EITT53287.2021.00024
Yusuf, A., Pervin, N., & Román-González, M. (2024). Generative AI and the future of higher education: a threat to academic integrity or reformation? Evidence from multicultural perspectives. *International Journal of Educational Technology in Higher Education*, *21*(1), 21. https://doi.org/10.1186/s41239-024-00453-6