Kashihara, A. et al. (Eds.) (2024). Proceedings of the 32nd International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Designing Learner-Centered Collaborative Learning by Incorporating AI-Based Teacher/Learner Agents with a Cognitive Model

Yugo HAYASHI[a*], Shigen SHIMOJO[b] & Tatsuyuki KAWAMURA[b]
[a]*College of Comprehensive Psychology, Ritsumeikan University, Japan*
[b]*Ritsumeikan Global Innovation Research Organization, Ritsumeikan University, Japan*
*y-hayashi@acm.org

Abstract: This paper presents collaborative concept-mapping tutor (CoCot ver.2), a collaborative learning support system that integrates concept maps with a conversational agent. CoCot ver.2 features two agents: a teacher agent and a student agent. The teacher agent acts as a human instructor, engaging in conversations with learners, aiding their metacognition, and summarizing the discussion content. The student agent learns from the learners' concept map creation and generates their own concept map knowledge. These agents are developed using (1) a cognitive architecture (ACT-R) for knowledge generation for the agents' concept map and (2) GPT 3.5 for part of the language processing for agent-based feedback.

Keywords: Computer-Supported Collaborative Learning, Intelligent Tutoring Systems, Conversational Agents, Cognitive Architecture

1. Introduction

Information and artificial intelligence (AI) technologies can be regarded as promising technology to provide learning support to learners engaged in group work. In addition, providing learning support based on domain-specific expertise and knowledge processing similar to that provided by human teachers is expected to enable individualized support for learners.

The development of learning support systems has been researched extensively, primarily in the fields of AI and educational engineering (Anderson, et al., 1995; Graesser, et al., 2005; Azevedo, et al.,2017). For example, Cognitive Tutor (Anderson, et al., 1995) is an intelligent learning support system that implements the cognitive Adaptive Control of Thought—Rational (ACT-R) architecture in a learning support system focusing on algebra. The practical research using this system has been conducted in numerous schools, and its effectiveness has been demonstrated.

On the other hand, learning support systems that utilize conversational agents for collaborative learning have also been studies in the past decade. In such studies, there have been studies that investigate the effectiveness of methods for presenting metacognitive suggestions using conversational agents whose responses are based on conversation analysis of collaborative learning activities between humans (Graesser, et al., 2005; Azevedo, et al.,2017). One attempt to use conversational agents in collaborative learning is to provide support by intervening as a third party to the learners. Foe example, in our previous study, we investigated how conversational agents that play different roles impact on explanation activities (Hayashi, 2019), and utilizing real time gaze feedback with combination of conversational agents facilitate learning process(Hayashi, 2020). Further, we demonstrated the usefulness of multimodal data such as gaze facial expression and language can be used for detecting learner's interaction process during the use of pedagogical conversational agent(Hayashi, in press).

However, certain concerns have been raised regarding these support methods. In these activities, the learners are at the center of the explanatory activity, and the AI tutor intervenes as a third party. Therefore, if learners ignore the AI tutor's instructions, it results in inadequate facilitation. This is because most studies on this topic rely on "vertical" facilitation methods (Hatano & Inagaki, 1991), in which AI systems provides advice unilaterally to the learner. Therefore, "horizontal" learning support method should be investigated, in which AI systems participate in the learners' explanatory activities as a member of their group, rather than offer unidirectional knowledge teaching to learners as a third party.

Then what kind of learning activities can play the role of vertical facilitation? Studies in learning science has conducted research on learning-by-teaching. This method is designed where learner plays the role of a teacher at a certain time in the classroom (Hanke, 2012). The learner in the teacher's role can present new topics to other learners, lead discussions, and help them solve their learning tasks. A tutoring system based on leaning by teaching methods has being developed in the fields in artificial intelligence and intelligent tutoring systems (Biswas, et al., 2005; Matsuda, et al.,2015). Furthermore, a system has been proposed that allows learners to teach what they have learned to a knowledge-teaching agent called Betty in the form of a concept map that mimics a semantic network(Biswas, et al., 2005). The learner presents a problem to Betty, who solves the problem using reasoning based on the concept map created by the learner. In turn, the learner gains a deeper understanding of the concept by reflecting on the concept map created by Betty and modifying the ideas appropriately. This approach can be interpreted as the "horizontal" mutual learning methods, because they agent will play the role of human students.

In this paper, we present collaborative concept-mapping tutor (CoCot ver.2) which is currently under development in our laboratory. This is a learning support system for collaborative learning incorporating learning support functions that includes both pedagogical facilitation and teaching knowledge to a virtual student.

2. System: CoCot(Collaborative Concept mapping Tutor)

This section presents the new collaborative learning support system that incorporates both "vertical" facilitation and "horizontal" mutual learning in collaborative learning situations.

In this system, learners understand concepts through explanatory activities about psychological concepts with a human partner using concept maps (Shimojo & Hayashi, 2021).In this learning task, pairs of university students engage in mutual explanatory activities about a specific field's concepts. While conducting these explanations, they can collaboratively create a concept map to aid in their explanations. Two types of conversational agents with distinct roles are included in the system for teaching in this task. The first aids metacognitive facilitation, serving as a teacher agent, and provides vertical support, while the other serves as a student agent, which learns the contents of the learner's concept map and generates a new concept map. In other words, the student agent teaches the learner how to create a concept map by example, and the learner learns by observing and referring to the generated examples (horizontal support).

CoCot ver.2, the learning method proposed in this study, is an intelligent learning support system in which an agent provides support in the form of reflections, while a pair of learners proactively perform explanation activities using concept maps. In this system, learners create concept maps with their collaborators while conversing with them via text chat. The conversational agent monitors the learners' concept maps and the contents of their conversation and provides advice and examples of concept maps to the learners based on (1) knowledge inference using cognitive architecture and (2) language analysis and sentence generation using large language models (LLMs). Learner in pairs is then presented with advice and concept map examples, and reflection on these facilitates their learning activities. The system communicates with a server, a client, and two agents and includes the following six main modules:

(1) a server that manages data for map drawing and logging,
(2) a client module that operates on the user side,

(3) a module for drawing concept maps,
(4) an agent that generates prompts,
(5) an agent that cooperates with the LLM (GPT 3.5), and
(6) an agent that cooperates with the cognitive architecture (ACT-R).

The system was developed using C# and linked to ACT-R, which is written in LISP language, using socket communication. Declarative knowledge implemented in the ACT-R was based on our previous study by Hayashi and Shimojo(2022).

As the next step, we plan to conduct empirical experiments using this system to evaluate its effectiveness.

Acknowledgements

This work was supported by This study was supported by the JSPS KAKENHI (grant numbers 23H03510).

References

Anderson, J.R., Corbett, A.T., Koedinger, K.R., Pelletier, R.(1995). Cognitive tutors: Lessons learned. *Journal of the Learning Sciences 4*(2), 167-207

Azevedo, R., Taub, M., Mudrick, N.(2017). Handbook of self-regulation of learning and performance, chap. Understanding and reasoning about reality cognitive, affective, metacognitive processes to foster self-regulation with advanced learning technologies. Routledge, New York, NY

Biswas, G., Leelawong, K., Schwartz, D., Vye, N.(2005). Learning by teaching: a new paradigm for educational software. *Applied Artificial Intelligence 19*(3), 363-392

Graesser, A., Chipman, P.and Haynes, B., Olney, A.(2005). Autotutor: An intelligent tutoring system with mixed-initiative dialogue. *IEEE Transactions on Education 48*(4), 612-618

Hanke, U.(2012). Learning by Teaching, pp. 1830.1832. Springer US, Boston, MA

Hatano, G., Inagaki, K.(1991). Sharing cognition through collective comprehension ac-tivity. In: Resuick, L.B., Levine, J., Teasley, S. (eds.) Perspectives on socially shared cognition, pp. 331-348. American Psychological Association, Washington, DC

Hayashi, Y.(2019). Multiple pedagogical conversational agents to support learner-learner collaborative learning: Effects of splitting suggestion types. *Cognitive Systems Research 54*, 246-257. https://doi.org/10.1016/j.cogsys.2018.04.005

Hayashi, Y.(2020). Gaze awareness and metacognitive suggestions by a pedagogical conversational agent: an experimental investigation on interventions to support collaborative learning process and performance. *International Journal of Computer-Supported Collaborative Learning 15*(4), 469–498.

Hayashi, Y., Shimojo, S.(2022). Modeling perspective taking and knowledge use in collaborative explanation: Investigation by laboratory experiment and computer simulation using act-r. In: Rodrigo, M.M., Matsuda, N., Cristea, A.I., Dimitrova, V. (eds.) *Proceedings of the 23rd International Conference on Artificial Intelligence in Education (AIED2022)* pp. 647-652. Springer

Hayashi, Y.(in press) Modeling synchronization for detecting collaborative learning process using a pedagogical conversational agent: Investigation using recurrent indicators of gaze, language, and facial expression, *International Journal of Artificial Intelligence in Education*

Matsuda, N., Cohen, W., Koedinger, K.(2015). Teaching the teacher: tutoring Sim student leads to more effective cognitive tutor authoring. *International Journal of Artificial Intelligence in Education 25*(1), 1-34.

Shimojo, S. Hayashi,Y.(2021). Facilitating explanation activities using a concept map in collaborative learning: Focusing on coordination and argumentation process, *Cognitive Studies: Bulletin of the Japanese Cognitive Science Society*, 28(4), 499-521