

A Systematic Literature Review of Adaptive Collaborative Systems Based on Dashboards

Kaouthar Soltani, Nadia Hocine^a and Karim Sehaba^b

CSTL laboratory, University of Mostaganem, Av. Hamadou Hossine, Mostaganem, Algeria
{kaouthar.soltani.etu, nadia.hocine, karim.sehaba}@univ-mosta.dz

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Abstract: Collaborative learning plays an important role in improving individuals' critical 21st century skills including teamwork, creativity, and critical thinking. Research studies in computer-supported collaborative learning relied on multiple technologies and analytics methods to analyze team members' interaction with the learning system. They generally seek to assess and support collaborative learning and aid instructors to orchestrate the classroom in co-located collaboration group settings. To enhance awareness among students and teachers about collaboration, learning systems often offer dashboards with visual presentations of educational data and collaborative work progress. Despite the growing research interest on adapting the systems for collaborative learning support, only a few studies investigated how dashboards can be adapted to improve students' learning and collaboration skills. This paper systematically reviewed research studies on adaptive learning systems based on dashboards, following the PRISMA protocol. The objective is to examine the role of dashboards in customizing learning systems and enhancing collaborative learning and teaching. This could pave the way for research opportunities in designing and developing future adaptive dashboards that foster collaborative learning.


1 INTRODUCTION


Collaborative learning refers to methods where a group of two or more students work together to perform tasks or solve problems in order to achieve a common objective (Lipponen, 2002). In addition to knowledge acquisition, collaborative learning helps students acquire multiple teamwork and collaboration skills. Many research studies in Computer-Supported Collaborative Learning (CSCL) suggested learning systems to support for instance communication, group awareness, and group monitoring. They employed various methods, such as learning analytics, multimodal analytics, social network analysis, and process mining, to examine behavioral patterns by analyzing interaction data of group members with the learning system. These methods often seek to help both students and teachers understand the collaboration process and assess the learning performance (Liu and Nesbit, 2020).

Recent studies in CSCL have focused on identifying the most relevant high-level constructs of edu-

cational and interaction data, also named indicators, that can inform actionable insights (Jorno and Gynther, 2018). This consists for instance in providing students with adaptive feedback and recommending activities that can improve their reflection and group awareness (Worsley et al., 2021). These indicators were also used recently to support teachers in classroom orchestration, especially in co-located collaboration group settings. However, interpreting these indicators in real-time and using them to make decisions can be challenging for both students and teachers. This difficulty stems from the volume of real-time data and indicators, which may not always align with the needs of students and teachers during the collaboration process.

Various learning systems emphasize dashboards that are used to report and visually present relevant collaborative learning indicators, using for instance tables, network graphs, and bar charts. They provide stakeholders with real-time feedback on students' progress, performance, and group dynamics (Lipponen, 2002). However, only a few studies dealt with the adaptation of learning dashboards to meet students and teachers needs along the collaboration process. In fact, the real-time adaptation of dashboards

^a  <https://orcid.org/0000-0001-7875-1064>

^b  <https://orcid.org/0000-0002-6541-1877>

have shown promise in improving group awareness and supporting teachers' interventions (Amarasinghe et al., 2021; Zamecnik et al., 2022).

The present review aims to study the adaptation techniques and the role of dashboards in adaptive learning systems that support collaborative learning. Adaptation in this paper refers to the process of tailoring the learning system content, feedback and interface without the direct intervention of a human. Our first research question is: **RQ1. How have adaptive learning systems based on dashboards contributed to improving collaborative learning and classroom orchestration?** We are also interested in the role of dashboards in adapting the learning system. Our second research question is: **RQ2. How have dashboards been utilized to provide adaptive support for collaborative learning?**

This paper is organized as follows: In section 2, we introduce the review methodology. Section 3 presents the results of the review by answering the previous research questions. Section 4 discusses the obtained results and presents some opportunities to advance research in adaptive systems based on dashboards.

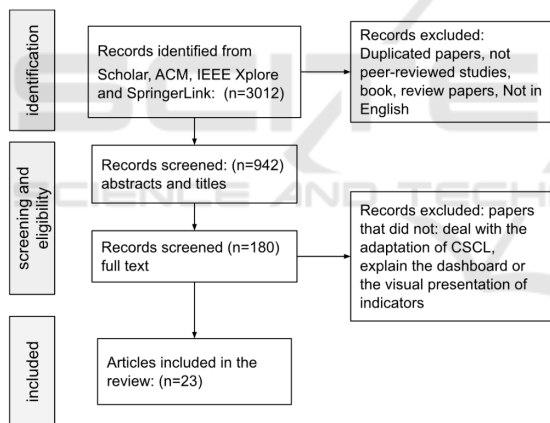


Figure 1: PRISMA paper selection process.

2 METHODOLOGY

The research methodology of the systematic review is in accordance with PRISMA protocol that provides guidance for the reporting of systematic reviews (Page et al., 2021). We followed the key steps of this protocol, including: searching papers using databases, screening the title and abstract of the papers to select eligible ones following exclusion and inclusion criteria, and reviewing the full texts of the most relevant papers. 23 research papers were found relevant to our research questions and were included in this review.

The general search process is shown in Figure 1. After formulating the research questions, we conducted a search to select and analyze relevant articles using inclusion and exclusion criteria. The search focused on different databases that are: IEEE-Xplore, Springer, ACM digital library, and Google Scholar. The general search query was: (adapt* OR personal*) AND ("computer supported collaborative learning" OR CSCL) AND (dashboard OR orchestr*). We searched for the keywords in the title, abstract, and keywords of the studies. Then, we skimmed inclusion and analysis criteria to determine whether the papers are eligible for our study.

We selected only papers published between 2017 and 2024 that are written in English. On the basis of the title and the abstract, only articles that suggested adaptive learning systems based on dashboards were included. CSCL environments that rely on authoring tools or adaptability (manual configuration of the system) were excluded. We also considered the type of articles as we excluded books, review papers, reports, and papers that are not peer-reviewed. Additionally, research studies that have not evaluated adaptive systems have been excluded, as they do not address our research questions. We then read the full text of the resulting papers to extract data following our analysis criteria to answer our research questions.

To answer the first research question RQ1, we have defined two analysis criteria:

- **User Targets:** we examine the stakeholders who use the dashboard and for whom the system is adapted.
- **Study Results:** this criterion investigates the effect of adaptive learning systems based on dashboards on collaborative learning and teaching.

We also defined the following two criteria to answer the second research question RQ2.

- **Adaptation Techniques:** we are interested in the adaptation techniques and how dashboards are incorporated into the adaptation process.
- **Collaborative Work Indicators:** we consider quantitative measures of interaction data used to assess the collaborative work as well as their visual presentation in the dashboard.

We identified 23 research papers that were relevant to our research questions. The review results indicate three kinds of dashboards that have been utilized in adaptive systems for collaborative learning support: Learning Analytics Dashboards (LAD), Multimodal Dashboards (MD), as well as Orchestration Dashboards (OD). In addition to LAD, which provides students and teachers with visual presentations of learning analytics results, recent studies have

suggested orchestration dashboards specifically designed to monitor classrooms in co-located collaboration. Furthermore, with the development of new input sources of data, such as sensor data, audio and video recording of students' collaborative activities, recent studies suggested adaptive multimodal dashboards. The latter is intended to help students obtain meaningful indicators about their learning status and collaboration process from the massive data generated during their interactions with the learning system.

The objective of adaptive learning systems based on dashboards was generally to improve students' knowledge building (Yang et al., 2023), self-regulation (Sedrakyan et al., 2020), teamwork skills (Lin et al., 2018), and learning outcomes (Han et al., 2021; Zamecnik et al., 2022). They also seek to provide teachers with adaptive support in orchestrating teams and identifying students who need assistance (Yang et al., 2023). The target users of the dashboards were the students (the number of papers $n=10$) and the instructors or teachers ($n=10$). Only in some recent studies, the stakeholders were both students and teachers. Teachers-facing dashboards have recently emerged as a relevant tool to support instructors in supervising and monitoring group members' collaboration process, track learning progress, and make decisions to improve classroom orchestration (Echeverria et al., 2023; Olsen et al., 2021).

As for students-facing dashboards, they were often designed to help students visualize their own performance, learning status, team progress, and receive feedback on their collaboration efforts (Sedrakyan et al., 2020; Zamecnik et al., 2022). They have also been used to monitor task distribution among team members and maintain their shared understanding of tasks (Han et al., 2021). Further, students-facing dashboards have been employed to communicate with instructors and ask help in the case of conflicting situations (Hadyaoui and Cheniti-Belcadhi, 2023).

2.1 Study Results

Table 1 summarizes the methods and main findings of the research studies. The result of the review shows that adaptive learning systems based on dashboards generally have a positive impact on students' learning outcomes (Edson and Phillips, 2021; Silva et al., 2023), team performance (Hadyaoui and Cheniti-Belcadhi, 2023), reflection (Echeverria et al., 2017) and social skills (Praharaj et al., 2022). Teacher-facing dashboards were also found effective in supporting teachers' intervention (Edson and Phillips, 2021; Fernandez-Nieto et al., 2024), enhancing the learning content (Kaliisa and Dolonen,

2023), improving orchestration actions (Amarasinghe et al., 2021), and reflection on orchestration strategies (Olsen et al., 2021; Yang et al., 2022).

Many studies have investigated the effect of dashboards on collaborative learning and teaching ($n=10$). Usability studies and comparisons between systems with and without dashboards have helped identify the role of dashboards in customizing and supporting collaborative learning and teaching. Studies showed the usefulness and efficiency of adaptive dashboards in supporting teams' reflection on their actions (Amarasinghe et al., 2020; Echeverria et al., 2017), participation, and learning outcomes (Han et al., 2021). They were also found useful for classroom orchestration to improve teacher awareness about team progression and collaboration issues (Yang et al., 2023) and to support their interventions (Amarasinghe et al., 2021; Edson and Phillips, 2021). Some studies also studied students' interaction with the dashboard and distinguished engagement patterns (Zamecnik et al., 2022) that can be used to improve the learning system adaptation.

2.2 Adaptation Techniques

Adaptive learning systems utilizing dashboards employed various adaptation techniques. Table 2 describes how the learning systems in the studies have been adapted. Learning systems often depend on real-time adaptive feedback via the dashboard ($n=10$). Adaptive feedback was suggested to assist team members who did not meet learning objectives (Serrano Iglesias et al., 2021; Zamecnik et al., 2022) and to improve students' social interaction (Hadyaoui and Cheniti-Belcadhi, 2023; Praharaj et al., 2022) and awareness of their learning progress (Aldosemani and Al Khateeb, 2022). It has also been provided to teachers in order, for example, to identify groups that need support (Han et al., 2021). In some studies, adaptive cognitive and reflective feedback was introduced outside of the dashboard to regulate the students' behaviors (Sedrakyan et al., 2020; Zamecnik et al., 2022) and to improve their self-regulation and reflective skills (Edson and Phillips, 2021).

Research studies dealing with adaptive support to teachers were generally focused on Artificial Intelligence (AI) based co-orchestration strategies ($n=6$) as well as group formation support ($n=3$). Teacher-facing dashboards were often developed for the co-orchestration of the classroom in co-located collaboration group settings. Some studies suggested group formation on the basis of the analysis of students' progress and learning performance (Olsen et al., 2021; Yang et al., 2021). Recent studies were in-

Table 1: Research studies methods and findings.

Paper	Research method	Study findings
Learning analytics dashboards		
(Lin et al., 2018)	Post study questionnaires, interactive visual analysis, and a post-test	Improved learning achievement and interest as well as visualizations usefulness
(Sedrakyan et al., 2020)	A case study of dashboard visualizations	Design recommendations
(Edson and Phillips, 2021)	Observation and structured interviews with teachers	The effectiveness of the dashboard in supporting teachers' intervention and improving learning outcomes
(Han et al., 2021)	Experiment to compare system using a LAD with a system without LAD	The dashboards improved students participation and argumentation outcomes
(Zamecnik et al., 2022)	Quantitative analysis of logs and qualitative analysis of students' perceptions of the usefulness of the LAD using surveys and focus groups	Different roles within teams have distinguished engagement patterns with the LAD, team leaders are actively more engaged with visualizations
(Aldosemani and Al Khateeb, 2022)	A design framework with examples of adaptive feedback	Design recommendations and adaptation challenges
(Hadyaoui and Cheniti-Belcadhi, 2023)	Pre-post tests of students learning, evaluation of predictive modeling approach	A positive impact of intra-group interactions on team performance
(Kaliisa and Dolonen, 2023)	Post study interviews with teachers	The dashboard usefulness and efficiency in monitoring the learning designs
(Silva et al., 2023)	A single-blind randomized controlled trial on the basis of logs and questionnaires to compare adaptive systems with a control condition	Adaptive scaffolds improved students course grades but without a significant impact on self-regulation skills
(Fernandez-Nieto et al., 2024)	A qualitative validation study using a retrospective reflection technique	Teachers satisfaction of the automated feedback and the generation of data stories that support student reflection
Orchestration dashboards		
(Martinez-Maldonado, 2019)	Post-study semi-structured interviews and questionnaires with teachers to evaluate the usefulness of the dashboard	Highlighted the teachers perspectives and issues: incompleteness of classroom data, feedback delay and the orchestration load
(Amarasinghe et al., 2020)	Experiment to validate the orchestration dashboard by analyzing logs data, video recording of experiment, and questionnaires	Meaningfulness of dashboard data and usefulness to support teams
(Amarasinghe et al., 2021)	A within-subject design to evaluate three conditions: personalized guidance, mirroring, and control condition (without dashboard)	The personalized guidance helped teachers to perform more orchestration actions
(Olsen et al., 2021)	Short interviews with teachers' to evaluate the orchestration support and thematic analysis of discourses	Improved teachers reflection on orchestration strategies and usefulness of AI support
(Yang et al., 2021)	Simulation of teaming configurations to evaluate the effectiveness and feasibility of dynamic group formation policies	A trade-off between the required knowledge heterogeneity and policy feasibility and a need for policies customization
(Yang et al., 2022)	Usability of the system by analyzing log data and observation	Teachers were able to manage the dynamic transitions and valued them
(Lawrence et al., 2022)	Observation of collaborative co-design sessions with the teacher and semi-structured interviews	Teachers preferred shared control with AI in pairing students
(Echeverria et al., 2023)	Workshop with student and teachers to discuss their experience through semi structured interview	The need for an hybrid control of the system by students and teachers and improve system adaptation
(Yang et al., 2023)	Post-study structured interviews and questionnaires	Usefulness of the orchestration tool
(Lawrence et al., 2024)	An in-person Wizard-of-Oz probe study, semi-structured interviews, and analysis of students discourse transcripts	Co-orchestration facilitated the transitions between individual and collaborative learning
Multimodal dashboards		
(Echeverria et al., 2017)	Post-study questionnaire and semi-structured interviews	The dashboard improved students post-hoc productive reflection about their activity
(Serrano Iglesias et al., 2021)	A use case of the integration of the system	A scenario to deploy and adopt MD in smart learning environments
(Praharaj et al., 2022)	Post-study analysis of team discourses and logs	Positive impact of role-role interactions on group's collaboration task

tended to support teachers in monitoring transitions between individual and collaborative activities. These studies usually employed intelligent tutoring systems that considered students' performance to make decisions about their learning modes. The dashboard played an important role in presenting the students' learning states and enabling rapid intervention by the instructor (Echeverria et al., 2023; Yang et al., 2023).

Visual presentations of indicators in the dashboards were also identified as a target of adapta-

tion in some research studies (n=5). Adaptive dashboards were designed to summarize group indicators and discover hidden patterns from interaction data (Martinez-Maldonado, 2019), aiding in visualizing indicators of learning progress (Han et al., 2021), participation, and social interaction in real-time (Kaliisa and Dolonen, 2023). Other studies have suggested network graphs with adaptive presentations that follow users' exploration of epistemic and social dimensions of group interaction (Echever-

Table 2: The adaptation techniques.

Adaptation technique	Description	Paper
Adaptive feedback	Adaptive cognitive and reflective feedback LAD with adaptive feedback to support team members who did not meet requirements Adaptive feedback through a dashboard to improve students social interaction Adaptive feedback based on regulation process phases (cognitive and meta-cognitive feedback) Real-time feedback to improve students thinking Adaptive feedback for teachers to identify groups that need help in real time using LAD Adaptive dashboard based on feedback on students' level of learning loss, preferences and instructional needs.	(Lin et al., 2018) (Fernandez-Nieto et al., 2024) (Zamecnik et al., 2022) (Serrano Iglesias et al., 2021) (Hadyaoui and Cheniti-Belcadhi, 2023) (Paharaj et al., 2022) (Sedrakyan et al., 2020) (Edson and Phillips, 2021) (Han et al., 2021) (Aldosemani and Al Khateeb, 2022)
Intelligent virtual tutor to support classroom orchestration	AI-based orchestration tool that supports dynamic transitions between individual and collaborative learning activities in the classroom AI co-orchestration tool using an adaptive tutoring system	(Yang et al., 2022) (Yang et al., 2021) (Lawrence et al., 2022) (Echeverria et al., 2023) (Yang et al., 2023) (Lawrence et al., 2024)
Adaptive visual presentations of indicators	A radar chart for patterns of each label representing essential elements of written argumentation Adaptive visual presentations of indicators about students participation and social interaction in real-time Personalized dashboard with data storytelling elements Adaptive visualization that summarizes group indicators and to discover hidden patterns from interaction data Multimodal analytics dashboard with adaptive visualizations (graphs) about epistemic and social aspects of collaboration	(Han et al., 2021) (Kaliisa and Dolonen, 2023) (Fernandez-Nieto et al., 2024) (Martinez-Maldonado, 2019) (Echeverria et al., 2017)
Adaptive scaffolds: guidance, prompts, and hints	Adaptive guidance and different types of prompts guide students through a regulatory support (scaffolds) and tips that depends log data Dashboard to guide orchestration based on Epistemic Network Analysis and an alerting mechanism that fagged critical moments in collaboration	(Lin et al., 2018) (Echeverria et al., 2023) (Silva et al., 2023) (Amarasinghe et al., 2021)
Adaptive collaboration and orchestration scripts	A teacher-facing dashboard that supports teachers in orchestrating scripted collaboration Adaptive collaboration scripts	(Amarasinghe et al., 2020) (Han et al., 2021)
Human-AI collaboration for group formation	Human-AI collaboration to orchestrate the classroom and support students who are struggling with an individual activity by pairing them with other students Dynamic group formation using various pairing policies	(Olsen et al., 2021) (Yang et al., 2023) (Yang et al., 2021)

ria et al., 2017). Recently, research has relied on storytelling techniques to summarize team progression data (Fernandez-Nieto et al., 2024).

Finally, some studies put forward scaffolding or collaboration scripts (n=6) based on guidance and different types of prompts (Echeverria et al., 2023; Lin et al., 2018). However, only a few studies have integrated the scaffolds in the dashboard. For instance, Amarasinghe, Ishari and colleagues developed an adaptive dashboard utilizing epistemic network analysis to guide orchestration, alongside an alert system highlighting critical collaboration moments (Amarasinghe et al., 2021).

2.3 Collaborative Work Indicators

Research studies were based on different quantitative measures related to learning context and objectives (see Figure 2). A wide range of studies investigated

team members' participation in learning activities and discussion forums to measure their engagement in the collaborative work (Han et al., 2021; Kaliisa and

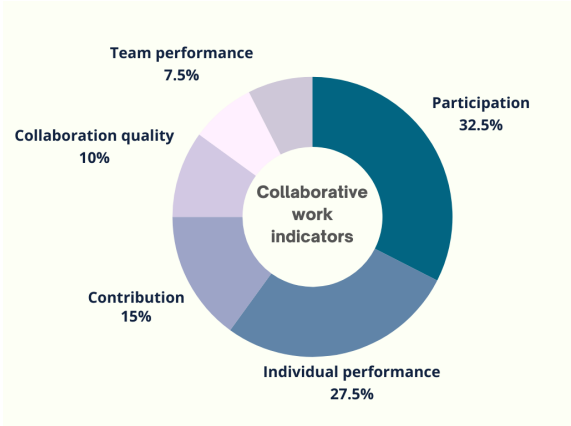


Figure 2: Collaborative work indicators.

Dolonen, 2023). Other studies considered epistemic aspects of collaboration, including team members' individual performance (Edson and Phillips, 2021; Olsen et al., 2021), learning progress (Lawrence et al., 2022), and their contribution to the knowledge construction (Hadyaoui and Cheniti-Belcadhi, 2023; Sedrakyan et al., 2020). Only a few studies introduced a quantitative measure of collaboration quality on the basis of the analysis of students' interaction with the learning system (Han et al., 2021; Prahara et al., 2022) and the communication between team members (Fernandez-Nieto et al., 2024; Silva et al., 2023).

Collaborative work indicators were generally provided to users through the dashboard using different visual presentation techniques. In particular, network graphs have been adopted by many recent studies as they have the potential to visualize both the epistemic and social dimensions of the interaction between team members (Amarasinghe et al., 2021; Zamecnik et al., 2022). Furthermore, simple shapes such as circles and triangles with different sizes and colors (Aldosemani and Al Khateeb, 2022; Silva et al., 2023), progress bars (Silva et al., 2023), as well as tables were used to highlight indicators of students' progression, performance, and contribution (Amarasinghe et al., 2020; Echeverria et al., 2023). Other studies suggested different types of charts, including bar graphs (Aldosemani and Al Khateeb, 2022; Hadyaoui and Cheniti-Belcadhi, 2023) and radar charts (Han et al., 2021).

3 DISCUSSION

Collaborative learning offers the opportunity to develop teamwork and communication skills. However, students may vary in terms of their prior knowledge, engagement, and social skills, which can impact their ability to work in a group. The review highlighted the role of dashboards in adaptive learning systems that can aid team reflection and improve participation and learning outcomes (Amarasinghe et al., 2020; Echeverria et al., 2017; Han et al., 2021). Dashboards can be also valuable for orchestrating classrooms, enhancing teacher awareness of team progress and collaboration issues (Yang et al., 2023), and facilitating targeted interventions (Amarasinghe et al., 2021; Francillette et al., 2012).

Adaptive learning systems using dashboards often emphasize real-time adaptive feedback and scaffolding based on prompts and hints (Hadyaoui and Cheniti-Belcadhi, 2023; Serrano Iglesias et al., 2021). However, some studies have not integrated feedback and scaffolding into the dashboard. Limiting the role of dashboards in adaptive scaffolding and collabora-

tion scripts can be attributed to the level of user control within the system and the objectives of the adaptation strategy (Brusilovsky, 2024). This strategy may aim to either guide students or enhance their self-regulation skills by reducing intervention from teachers or the system and fostering reflective learning. In fact, it is still challenging to determine how and when to adapt collaborative learning support based on the targeted skills of students to enhance their learning and skills.

Other research studies were based on the adaptation of the dashboard by selecting relevant indicators of epistemic and social aspects of collaboration. In addition to statistics charts, network graphs have been adopted by many recent studies as they have the potential to visualize different dimensions of the interaction between team members (Amarasinghe et al., 2021; Zamecnik et al., 2022). However, there is a lack of studies that examine the impact of visual presentations in the dashboard on the behavior and engagement of students and teachers. Furthermore, dashboards in most cases were designed for specific learning contexts, presenting students with indicators of their collaborative work without explaining how these indicators could help them enhance their collaborative learning.

A growing research interest has recently been devoted to improving the meaningfulness and explainability of data and their visual presentations in the dashboard. Recent studies focused for instance on game-based strategies such as storytelling to summarize team progression data (Fernandez-Nieto et al., 2024). Research opportunities in this area can focus on developing dashboards that fulfill the needs of learners and teachers during collaboration. These dashboards should offer meaningful indicators and explanations of their utility in enhancing learning outcomes and skills.

Finally, teacher-facing dashboards in adaptive learning systems generally focus on supporting teachers in group formation and managing the learning workflow, especially in scenarios combining individual and collaborative learning (Echeverria et al., 2023; Yang et al., 2023). The system usually recommended orchestration strategies while leaving control to the teacher, potentially leading to overload when managing multiple interventions in co-located collaboration group settings (Amarasinghe et al., 2021; Hakami et al., 2024). Future research studies should consider designing and evaluating dashboards that incorporate teachers' orchestration and pedagogical strategies to reduce the cognitive load associated with classroom monitoring (Hocine et al., 2019).

4 CONCLUSIONS

In this paper, we reviewed adaptive learning systems based on dashboards that are designed to support collaborative learning and teaching. The results have shown the potential of the dashboards in helping students to improve their learning and to assist teachers to monitor their classes. However, the adaptation of dashboards to students and teachers needs is still limited and more research studies should investigate how to personalize the dashboard according to, for instance students' learning needs, as well as teachers orchestration and pedagogical strategies. Moreover, future research opportunities can deal with AI techniques to support the analysis of students' collaboration issues and their assistance through the dashboard.

Finally, although the review provides insights of the use of dashboards in CSCL, it has some limitations. We focused solely on peer-reviewed studies of adaptive learning systems to explore the role of dashboards. The search databases were limited because of some access limitations. We reviewed only studies on collaborative learning in education, excluding those on professional development and cooperative learning systems. Finally, future meta-reviews of dashboards in adaptive and non-adaptive systems can facilitate comparative analysis of study findings and assess the impact of dashboards on learning outcomes as well as teaching practices and strategies.

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