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Teacher-Led Debriefing in Computer-Supported Collaborative Learning Pyramid Scripts

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Abstract: Debriefing is an integral part of orchestration and provides a space for teachers to review the learning experience. Although this concept is not new, little is known about how debriefing is conducted in scripted computer-supported collaborative learning situations, and its effects on students' learning gains. Moreover, there is a lack of studies providing evidence of how learning analytics can be effectively utilised to support teacher-led debriefing. The objective of this study is twofold: Firstly, it studies how debriefing impacts students' learning gains in Pyramid pattern-based learning situations. Secondly, it explores the types of learning analytics indicators that can support debriefing. Results indicated that debriefing can contribute to improve students' learning gains, however, it does not always lead to the optimal outcomes and the type of task can have a major influence. Mechanisms such as semantic similarity score, knowledge graph visualisations and flag features are scrutinized as options to support debriefing.

Keywords: CSCL scripts, Orchestration, Debriefing, Learning analytics.

Introduction

The notion of orchestration refers to the complexity associated with real-time management of educational scenarios seeking effective learning (Dillenbourg, 2013). Teachers' role in orchestration is known to be demanding as they have to regulate in real-time multiple actions that also occur in different social planes: individual, teams and class levels (Dillenbourg, 2013). For instance, at the teacher-individual level teachers may support students to clarify their doubts about the learning task at hand. At the team level teachers may engage in forming groups, evaluating both epistemic and social aspects of collaboration. At the class level teachers may be engaged in effectively coordinating learning activities planned for the class time or conducting teacher-led debriefing activities to support reflection at the end of lessons. The ultimate objective of the aforementioned diverse teacher-centric actions is to enhance students' learning gains. However, which orchestration actions are beneficial, or in other words, which orchestration actions support to maximise students' learning gains, has received less research attention.

As noted in Dillenbourg (2008) debriefing is an important phase in orchestration that may support students' learning. Although the term debriefing is variously defined in different contexts, (Lederman, 1992) in the learning situations it can be understood as a guided reflection phase (that usually occurs at the end of learning activities) where teachers comment on "what has been done in order to extract concepts or principles to be taught" (Dillenbourg, 2021). On the one hand, learners benefit from debriefing sessions as they provide a space to reflect on their knowledge as well as to learn from their own mistakes. On the other hand, debriefing can become a demanding task for teachers as they need to generate a final summary on the fly reflecting on what learners did learn, why and what are the implications for both educators and students. In complex learning situations such as Computer-Supported Collaborative Learning (CSCL), debriefing can become more demanding and challenging to teachers as they require to prepare a final summary considering diverse aspects, e.g., social and epistemic aspects, of the learning situation. Although it's a demanding task on teachers' side, it is an important activity on students' side as it ensures that all groups have acquired targeted knowledge (Dillenbourg, 2002).

Learning Analytics (LA) techniques can be effectively utilised to support orchestration. For instance, in the context of CSCL, digital traces (log data) collected from the underlying online learning platforms can be analysed using LA techniques to generate automatic summaries of group processes. Different types of analytics, e.g., checkpoint and process analytics, (Lockyer, Heathcote, & Dawson, 2013) can be used to detect learning patterns also with reference to the learning design, encouraging teachers to make necessary pedagogical actions and interventions, e.g., on-the-fly adaptations to learning design that are beneficial for learning. Recently, a growing research interest in deploying a variety of teacher support provisions, such as teacher-facing LA dashboards, has gained a lot of attention within the LA research community (Schwendimann et al., 2017). Existing studies have illustrated that such LA tools can facilitate teachers by increasing their awareness regarding group processes and to conduct on-the-fly script adaptations therefore supporting activity regulations in real-time (Amarasinghe et al., 2021a). However, what types of LA indicators are useful for the teachers to prepare and deliver impactful debriefing sessions that maximise students' learning gains have not been fully explored yet (Dillenbourg, 2021). To this end, in this study, we focused specifically on teacher-led debriefing actions as this phase of orchestration, despite its relevance, has received less research attention from both CSCL and LA research communities. In this regard, some important questions to be explored are: what is the effect of teacher-led debriefing on students' learning gains in scripted CSCL situations and what types of LA indicators can support teachers to deliver debriefing. Our study context is situated in scripted CSCL situations, in particular collaborative learning activities structured according to the flow structure proposed in the Pyramid collaborative learning flow pattern (Amarasinghe, Hernández-Leo, Ulrich Hoppe, 2021).

Background

The historical origin of the concept of debriefing is related to the military, where debriefing is used as an aid to review what happened during a collective training exercise in order to provide performance feedback at both individual and group levels (Morrison & Meliza, 1999). Apart from the army's methods of delivering debriefing, specialised forms of debriefing such as critical incident stress debriefing (CSID) is also used in the field of psychology to help people deal with trauma or disaster (Mitchell & Everly, 1997) and in the context of sports to evaluate team's performance and to facilitate self-reflection (McArdle et al., 2010). In educational settings debriefing is commonly used as a post-experience analysis in experiential learning activities, e.g., simulations and game-based learning tasks (Lederman, 1992). In such situations debriefing aims to process the learning experience in order to provide insights and to facilitate learning by examining the effects the learning experience has generated (Lederman, 1992). In simulation-based learning scenarios in nursing education, debriefing can occur after the simulation event, i.e., *post-event debriefing,* or during the simulation event, i.e., *within-event debriefing* which causes interruptions to participants' actions when errors occurred (Sawyer et al., 2016). Post-event debriefing can either be guided by an instructor or can be performed by individual students, or can be done in teams (Sawyer et al., 2016). Dufrene &Young (2014) have concluded that debriefing conducted following simulations is effective and can lead to improved performance scores and students' self-perception of confidence regardless of debriefing strategy used.

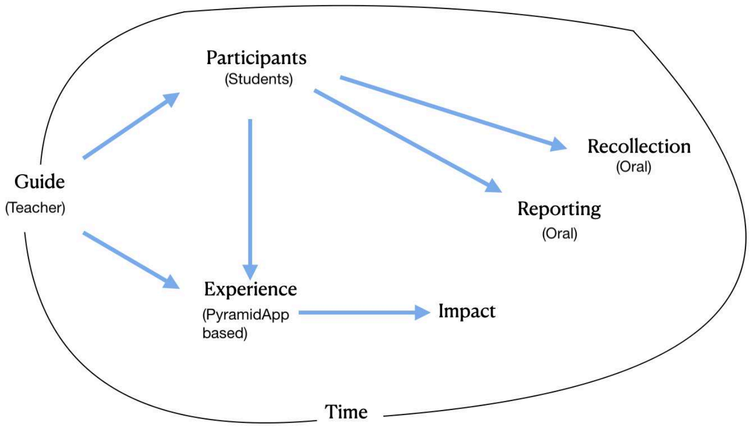
Debriefing can be considered as a contingent task teachers require to perform during orchestration (Dillenbourg, 2013). It demands teachers to elaborate on students' performance levels and responses in real-time (Dillenbourg & Jermann, 2010). In the context of scripted collaboration debriefing usually occurs at the final stage of the script (Weinberger et al., 2007). For instance, in an argumentation script called *ArgueGraph* a tool provided individual and group choices to a given task as well students who changed their choices as they move from individual to group levels in the script. It was expected that such information can facilitate debriefing by allowing teachers to detect choices that require further explanation or reformulation as well as to ask students reasons for their change of mind (Dillenbourg, 2013). In another study, a *teacher cockpit* has been developed to facilitate debriefing during *ConceptGrid* script-based collaborative learning situations (Weinberger, 2007). The tool facilitated teachers to annotate answers (using different color codes) that they want to refer back during the debriefing session. Some other studies have reported how LA supported debriefing in real classroom collaborative learning situations (Do-Lenh et al., 2012, Shahmoradi et al., 2019). Within a tool called *TinkerBoard* debriefing support was provided to the teachers by allowing them to compare the similarities and differences between warehouse models (via a *comparison zone*) generated by student groups. Authors concluded that having access to *comparison zone* reduced the time teachers required to prepare debriefing. The tool also facilitated teachers to refer to intermediate solutions and related statistics during debriefing (Do-Lenh et al., 2012). In (Shahmoradi et al., 2019) a teacher-facing LA dashboard was used to display students' interactions with an educational robot in a path-finding activity. The dashboard visualised LA indicators related to group performance, and the status of the robot. Instructors referred to information presented in the dashboard during debriefing and commented on students' performance during the activity as well as how the activity is related to the learning goals. However, the aforementioned studies have not reported to what extent debriefing influences students' learning gains and the details about teachers' preferences towards LA indicators that can support debriefing. Moreover, debriefing activities can become complex in collaborative learning situations that propose group structure changes over time, e.g., formulating small groups first and then larger groups in Pyramid pattern. In summary, although the concept of debriefing is not new, and is widely used across different contexts, little is known about what is the pedagogical value debriefing adds to students' learning gains and how LA can be best utilised to support debriefing.

Methods

Debriefing process and measurements of learning gains

As described in Lederman (1992) there are seven common elements of the debriefing process namely: 1) guide or debriefer; 2) participants; 3) experience; 4) impact of the experience; 5) recollection of the experience; 6) reporting out on the experience; and 7) time to process it. In the following, we provide the details of our study referring to the seven elements described above (see Figure 1). In our study two teachers conducted four online CSCL activities (see Table 1). Undergraduate students in the respective classes took part in the CSCL activities after providing informed consent to use their data for research purposes. The learning experience was technologically mediated in online learning situations using a web-based tool called PyramidApp that implements a particularisation of the Pyramid script (Amarasinghe, Hernández-Leo, Ulrich Hoppe, 2021).

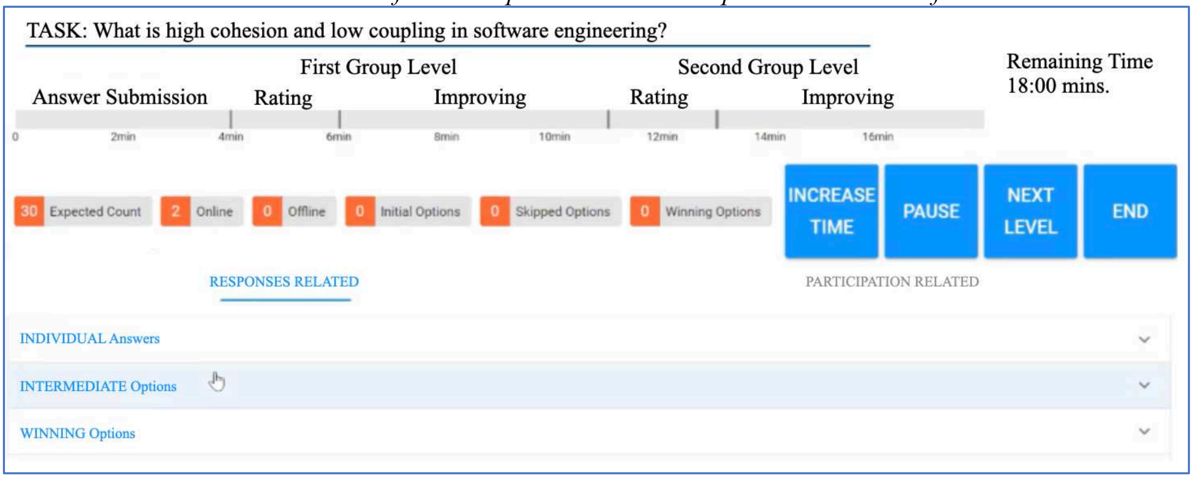
Figure 1
Debriefing process adopted from Lederman (1992)



Within the PyramidApp collaboration is structured as follows. After login into the tool, students require entering an individual answer for a given problem (*individual answer submission level*). Then students are randomly allocated into small groups (*first group level*). In small groups, students then evaluate the options submitted by peers individually using a rating mechanism built into the tool (*rating*). Next, they engage in discussion at the small group level and attempt to improve existing options collaboratively (*improving*). Based on the majority agreement an improved answer or a highly voted individual answer is automatically promoted to next larger group phase of the script for further evaluation (*second group level*). Large groups are formulated by merging small groups automatically. Within larger groups, students again engage in an individual rating of the options selected from the previous level (*rating*) and then further improving the selected options (*improving*). Likewise, the Pyramid script structures collaboration following a pyramid pattern within varying group sizes (first small and then in larger groups) until a consensus is reached on a given problem. A teacher-facing LA dashboard that is being built onto the PyramidApp aims to support teachers in orchestrating collaboration (Amarasinghe, Hernández-Leo, Ulrich Hoppe, 2021). It should be noted that the dashboard was not specifically designed to support debriefing, but to provide orchestration support.

At the end of each Pyramid activity students answered a first questionnaire (1stQ) which asked them to write an answer to the same task. The objective of administering the 1stQ was to evaluate students' learning before and after they underwent the Pyramid activity. The expectation here was that the PyramidApp based learning experience has affected students in a meaningful way therefore contributing to learning gains. Once students finished answering the 1stQ, teachers of the respective sessions conducted debriefing (see Table 1). It was observed that during debriefing both teachers focused on the content produced by students (epistemic facet of the learning situation). For instance, teacher A mentioned that "I mostly look at the final answers submitted by the students during debriefing and also sometimes the intermediate ones selected and then comment about those with the whole class." Teacher B mentioned that "I construct the discussion based on students' responses. Students also contributed to the recollection of the learning experience." After debriefing the students were asked to respond to a second questionnaire (2ndQ) which again asked them to write an answer to the same task based on any new knowledge they acquired from the debriefing session conducted by the teacher. The expectation here was that the debriefing will help to further enhance students' learning gains when compared to the learning they already achieved by participating in the Pyramid CSCL activity.

Figure 2
Information presented in the Response Related tab of the dashboard



We used both precision and confusion scales presented in our previous work (Amarasinghe et al., 2021b) to report students' learning gains. The level of precision can be defined as the "degree of agreement between a particular measurement (student's response) with an accepted standard (teacher's response)" (Amarasinghe et al., 2021b). The level of confusion can be understood as the "degree of misunderstanding present in a student's response (e.g., mistakes, misconceptions, incorrect ways of organizing facts and figures)" (Amarasinghe et al., 2021b). Both precision and confusion measures were important to be considered as those measures provided different but complementary information about learning gains, e.g., precision indicates the agreement of students' answers with teachers' expectations, confusion is important because students could learn from their own mistakes.

The main data source used for the analysis were the individual answers students submitted at the beginning of the Pyramid activity and the responses submitted to the 1stQ and 2ndQ. Teachers manually assess all responses to indicate the level of precision and levels of confusion. The level of precision was measured using a 4-point item from "not precise", "slightly precise", "almost precise" and "precise". The level of confusion was also measured using a 4-point item from "none", "low", "intermediate" and "high".

Table 1
Details about Pyramid activities conducted by two teachers

Teacher	Course Name	Activity ID	Task	Duration	Total Students
A	Computer Engineering (Undergraduate Course)	TA-1	Identify errors in a software code and propose ways to fix errors.	14 mins.	15
	Statistical Methods (Undergraduate Course)	TA-2	Choose the appropriate statistical method to calculate a variable's probability.	14 mins.	26
B	Software Engineering (Undergraduate Course)	TB-1	What is high cohesion and low coupling in software engineering?	18 mins.	27
		TB-2	In which ways, people in the software industry would behave unethically in their regular professional practices and projects?	20 mins.	14

LA indicators to support debriefing

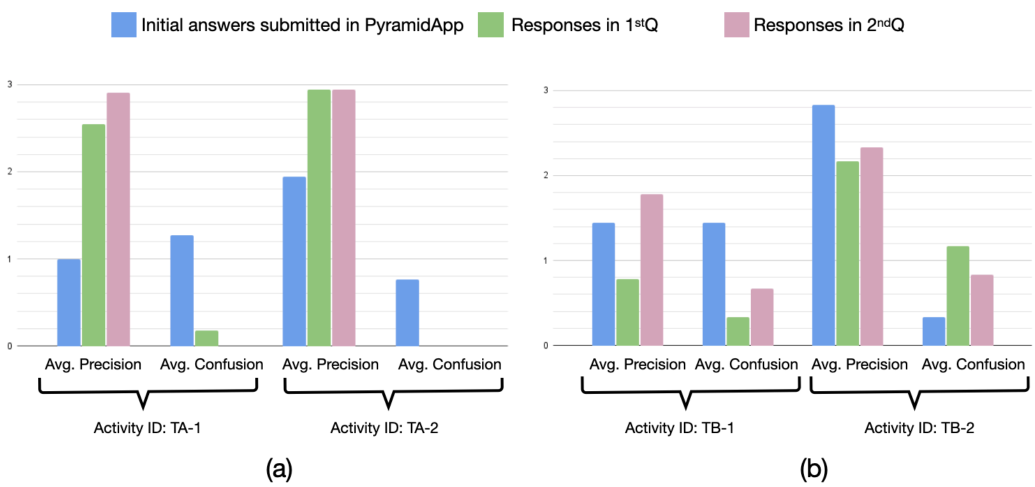
To better understand teachers' preferences towards LA indicators that can support debriefing and to facilitate the inter-stakeholder conversation involved in implementing the LA innovation we followed a human-centered LA approach. In particular, OrLA framework support the conversations between different stakeholders, i.e., researchers, LA system developers and teachers, when designing LA innovations to be used in everyday classroom practice (Prieto et al., 2019). In this study, the co-design interviews took place between one developer who was previously involved in developing the PyramidApp, two teachers who conducted the Pyramid sessions described above (A and B) and a researcher who is also an author of this paper. Main points discussed during the co-design conversations are presented in the following section.

Results

Impact of teacher-led debriefing on students' learning gains

Figure 3 shows the average precision and average confusion detected in students' answers in teacher A and teacher B sessions. As shown in Figure 3(a) in the first activity (TA-1) the precision of students' answers has increased after participating in Pyramid activity and further increased after debriefing. The levels of confusion present in students' answers were reduced after participating in the Pyramid activity and reached the level of zero after debriefing. In the second activity (TA-2), the levels of precision in students' answers increased after participating in the Pyramid activity. However, the average level of precision in students' answers has not changed after debriefing (same value). Moreover, the levels of confusion presented in students' answers had reached a minimum (zero value) after participating in the Pyramid activity and remained constant after debriefing as well.

Figure 3
Average precision and confusion in students' responses



As shown in Figure 3(b) in teacher B sessions, during the first activity (TB-1) the precision of students' answers has decreased after participating in the Pyramid activity, however, later increased after debriefing. The level of confusion presented in students' answers decreased after participating in the Pyramid activity. However, the average level of confusion in students' answers slightly increased after debriefing when compared to the levels of confusion presented in students' improved answers submitted immediately after the Pyramid activity. In the second activity (TB-2) the precision of students' answers has decreased after participating in the Pyramid activity, and later increased after debriefing. However, the confusion in students' answers has increased after participating in the Pyramid activity but then decreased after debriefing. Overall, the results indicate that debriefing was helpful but it did not lead students to achieve the highest levels of precision and the lowest levels of confusion in all activities. This indicates the interest of exploring additional support that could help teachers in preparing the most possible productive debriefing sessions.

Teachers' preferences towards LA indicators to support debriefing

Three different LA indicators were proposed as a result of the co-design conversations that took place between a researcher, a developer and the teachers. The proposals considered teachers' current debriefing practice that focused on the epistemic facet of the learning situation (described above) and were also informed by the previous work (Do-Lenh et al., 2012, Weinberger et al., 2007). The proposals were named as 1) *Semantic Similarity Score* (Figure 4); 2) *Knowledge Graph* (Figure 5); and *Flag Feature* (Figure 6). *Semantic similarity Score* and *Knowledge Graph* aimed at using natural language processing techniques. For instance, *Semantic Similarity Score* can indicate the semantic similarity between teachers' model answers and students' answers. A high score (given as a percentage in Figure 4) indicates students' answers are similar to teachers' answers and a lower score indicates deviations. The *Knowledge Graph* aims to automatically generate a summarised graph that shows how important concepts presented in students' answers are connected and the relations between them. Finally, the *Flag Feature* is a non-automatic method and aims to facilitate teachers to filter answers that consist of highly confusing elements as they read different options submitted by students during the activity.

Figure 4
Semantic Similarity Score Visualisation

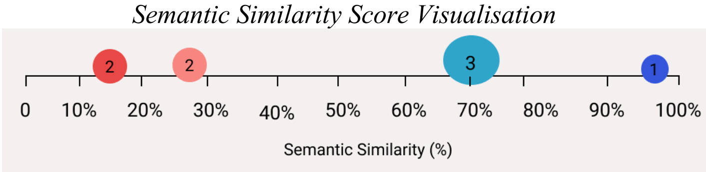


Figure 5
Knowledge Graph Visualisation

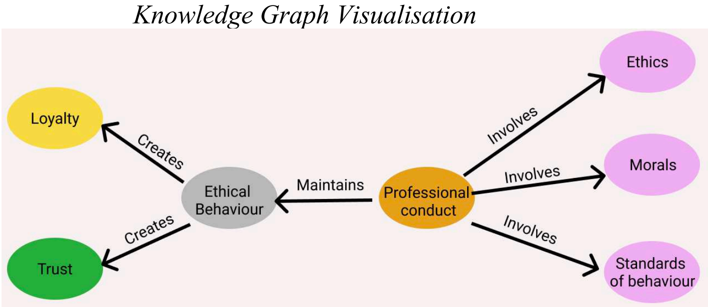


Figure 6
Flag Feature

Student Name	Answer Submitted	Flag Answer
James	Cohesion shows the relationship within the module. Coupling shows the relative independence between the modules.	☐
Emma	High cohesion means modules perform one task, low coupling means your module is independent.	☐
Peter	Provide a better designed code that is easier to maintain.	☑

Teachers provided feedback and proposed improvements for the aforementioned LA indicators after evaluating the usefulness of each indicator to support debriefing. First, regarding *Semantic Similarity Score* (Figure 4) teacher A mentioned that it can help to detect the number of students who submitted answers that are deviating from teachers' model answers (the number of students is indicated within circles in Figure 4). Teacher A further commented that this indicator would be more useful during the run-time of the activity (instead of debriefing that occurs at the end of the activity) as she can observe whether a majority of students are deviating from the expected (model) answer which hints the need for further explanation of the task. Moreover, teacher A proposed improvements (e.g., "Similarity percentage is not enough. I need to know what they did wrong in their answer or the reason for having a low similarity score.") Teacher B highlighted that knowing more about dissimilarities is useful during debriefing (e.g., "It provides an easy detection on the performance.") Regarding the *Knowledge Graph* (Figure 5) both teachers mentioned that it provides a useful summary but proposed to improve the width of the network edges to represent students' knowledge (e.g., "Using the visualisation I can see a summary of knowledge produced by the whole class. It would be nice if the edges of the network represent the percentage of students who contributed to it. This way I can know what relationships most of them did understand and what type of relationships are difficult to understand.") Finally, regarding the *Flag Feature* (Figure 6) both teachers agreed that it can be useful during a small class but could create problems in a large class (e.g., "Using the flag feature I can select answers that I think are useful to be discussed with the whole-class. But with a large class, I might not have time to read all answers and flag which ones I want to discuss during debriefing.")

Discussion

The findings of the study indicate that PyramidApp based CSCL activities and teacher-led debriefing influence students' learning gains. For instance, in teacher A sessions, CSCL activities were beneficial as those sessions helped to achieve learning gains (increased precision and decreased confusion in answers submitted right after the activity). Moreover, in the first activity (TA-1), debriefing helped to increase precision and to reduce confusion indicating that teacher-led debriefing is important to achieve learning gains. Interestingly it was also noted that the debriefing intervention did not lead to increase precision in students' answers in the second activity (TA-2). These findings can be interpreted by referring to the type of task. In the case of teacher A sessions, the tasks given to students are closed-ended, meaning students can produce a limited set of possible answers. In such situations, precision can be increased until students reach the maximum set of possible answers and confusion can be decreased to avoid any wrong answers. Regarding teacher B sessions, both TB-1 and TB-2 activities resulted in reducing precision in students' answers after participating in Pyramid activities. However, debriefing has helped to increase precision to a great extend in TB-1 and slightly in TB-2. These findings show that debriefing is a crucial orchestration task that provides a space for the teachers to discuss students' artefacts with the whole class. (Dillenbourg, 2013). Moreover, unlike in teacher A sessions, in teacher B sessions, teacher-led debriefing has not contributed to eliminating confusion in students' answers in its entirety. A possible explanation for these results can be provided again by referring to the type of task. In teacher B sessions, the tasks given to students are open-ended that allows students to provide free-form answers. Although it is expected that such tasks provide an opportunity for students to negotiate and co-construct solutions the findings indicate that the propagation of confusion is common in such activities. These findings are in alignment with our previous study findings (Amarasinghe et al., 2021b). Moreover, the results show that debriefing is a demanding task and cannot be entirely prepared in advance and may require improvisation in real-time (Dillenbourg & Jermann, 2010). The aforementioned findings indicate that teachers may benefit from having access to additional support from relevant LA indicators to conduct productive debriefing sessions especially when the tasks given to students are open-ended in nature. Additional support could also facilitate to lower the orchestration load experienced by the teachers (Shahmoradi et al., 2019). The qualitative data collected from teachers also shed light on the design requirements of different LA indicators to support debriefing. In the future, we are planning to integrate the proposed LA indicators into the existing teacher-facing dashboard and to study the usefulness of those indicators to deliver more focused debriefing sessions as well as how such additional support influences teachers' orchestration load.

There are several limitations of this study. First, regarding the learning gains evaluation, we have only considered four sessions conducted by two teachers, and the courses were oriented towards information technology and computer science. Although the findings of our study indicate that debriefing could improve students' learning gains, we acknowledge that the limited number of sessions considered prevented us from producing generalisable study findings, rather allowed us to provide first insights. Moreover, manually assessing students' answers to report the level of precision and confusion-related elements became a demanding task for the teachers due to their time constraints and we could not extend our analysis beyond four sessions. Regarding the LA indicators evaluation studies, the limited number of teachers who participated, as well as the similarities in their backgrounds (e.g., information and communication technologies) can influence the design decisions. A larger sample of teachers with various backgrounds could have reported different needs for the proposed LA indicators.

Conclusions and Future Work

This study provides evidence on the importance of teacher-led debriefing activities on students' learning gains in the context of scripted CSCL sessions. We believe that debriefing as a task within orchestration has received less attention and its influence on students' learning gains has not been broadly investigated. Our study contributed to addressing this gap in research. Study findings indicated that debriefing is crucial to improve students' learning gains, however delivering an activity summary spontaneously can become a challenging task for the teachers, especially in situations where students work on tasks that are open-ended in nature. Future studies that could build on our work include: (1) How debriefing influence teachers' orchestration load; (2) Explore adequate LA indicators to support debriefing with a larger group of teachers; (3) Conduct more experiments to evaluate how the findings of the current study generalise to different types of tasks; and (4) Advance towards automatic measurement of precision and confusion in students' answers.

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