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Collaborative activities in hybrid learning environments: Exploring teacher orchestration load and students' perceptions

Alejandro Ortega-Arranz [a,*], Ishari Amarasinghe [b], Alejandra Martínez-Monés [a], Juan I. Asensio-Pérez [c], Yannis Dimitriadis [c], Mario Corrales-Astorgano [a], Davinia Hernández-Leo [b]

[a] *School of Computer Engineering, Universidad de Valladolid, Valladolid, 47011, Spain*
[b] *Department of Engineering, Universitat Pompeu Fabra, Barcelona, 08018, Spain*
[c] *School of Telecommunications Engineering, Universidad de Valladolid, Valladolid, 47011, Spain*

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ABSTRACT

The recent Covid-19 pandemic made universities rethink their traditional educational models, shifting, in some cases, to pure online or hybrid models. Hybrid settings usually involve onsite (*i.e.*, in the classroom) and online (*e.g.*, in a different classroom, at home) students simultaneously under the instruction of the same teacher. However, while these models provide more flexibility to students, hybridity poses additional challenges for the specific case of collaborative learning, likely increasing the teachers' orchestration load and potentially hampering fruitful interactions among learners. In order to gather empirical evidence on the impact of hybridity in collaborative learning, this paper reports a study conducted in a hybrid classroom where a Jigsaw collaborative pattern was implemented with the Engageli software. The study involved 2 teachers and 67 students enrolled in a computer science undergraduate course. Teachers' post-interviews, questionnaires and an epistemic network analysis (ENA) were used to produce study findings. Results show that teachers reported a medium-to-high orchestration load for implementing and setting up the collaborative activities in the hybrid classroom. Among the factors that contributed most to such load, teachers highlighted the creation and live management of groups and collaborative documents. Additionally, the ENA showed that teachers put much effort on monitoring group interactions and solving technical issues. Finally, we observed relevant differences on students' perceptions (*e.g.*, satisfaction with the attention received by the teachers) based on the cohort sizes and on the students' attendance modality (onsite vs. online).

1. Introduction

The restrictions derived from the Covid-19 pandemic further evidenced the potential of hybrid learning environments, attracting the attention of higher education institutions (Eyal & Gil, 2022; Gil et al., 2022). International agencies such as UNESCO (UNESCO, 2020) and the European Commission (European Commission, 2020) are also supporting this transition towards hybrid and online

* Corresponding author.
E-mail addresses: alex@infor.uva.es (A. Ortega-Arranz), ishari.amarasinghe@upf.edu (I. Amarasinghe), amartine@infor.uva.es (A. Martínez-Monés), juaase@tel.uva.es (J.I. Asensio-Pérez), yannis@tel.uva.es (Y. Dimitriadis), mcorrales@infor.uva.es (M. Corrales-Astorgano), davinia.hernandez@upf.edu (D. Hernández-Leo).

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educational models. One popular hybrid learning model (Eyal & Gil, 2022) merges onsite (*e.g.*, in the physical classroom) and online (*e.g.*, out of the physical classroom) students at the same time synchronously (Raes et al., 2020).

Hybrid learning models provide the possibility of remote participation in face-to-face sessions, allowing more flexible ways of following courses than in brick and mortar universities (*e.g.*, students that avoid pure online learning). Additionally, these models also provide flexibility to those students that prefer to attend physically to the classroom but who sometimes cannot (*e.g.*, students that reside far from the institution). However, these hybrid learning models are likely to demand an additional effort from teachers such as designing learning activities (and their associated resources) which will be carried out by both onsite and online students, answering onsite and online questions through different communications channels, etc. (Prieto et al., 2017). In the Technology-Enhanced Learning (TEL) field, this increase in teacher workload when introducing innovations supported by technology has been studied under the umbrella of the so-called teacher orchestration (Dillenbourg, 2013; Tchounikine, 2013). Teacher orchestration has attracted a lot of attention in the last few years (*e.g.*, Feng et al. (2023)) because it is a key factor affecting the overall learning experience of the students, and the potential adoption of teaching innovations supported by technology, among other factors. Therefore, it is relevant to understand the implications of hybrid learning from the perspective of teacher orchestration load, especially when hybrid learning is combined with active learning strategies such as Collaborative Learning.

Collaborative Learning, in which learning is fostered by means of social interactions among students (Dillenbourg, 1999), also poses its own orchestration challenges to teachers (Amarasinghe et al., 2021). For instance, managing unexpected events in the composition of groups (*e.g.*, students not showing up), or managing the exchange of learning artifacts among groups (specially when the number of groups is high). The orchestration load derived from learning scenarios combining hybrid and collaborative learning might lead to a barrier for teachers that might also affect the students' perceptions towards these hybrid models (*e.g.*, the satisfaction of the students with the attention received by the teachers during the collaborative activity). Given this context, students' perceptions can be seen as a way to check whether orchestration decisions were adequately executed during the learning activities. This study aims to understand which factors in hybrid and collaborative learning scenarios affect teacher orchestration load with the ultimate goal of improving the technological support for these scenarios.

Previous studies have focused on the impact of teaching in hybrid learning environments with synchronous online and onsite students, *e.g.*, Huang et al. (2017). Two of these studies (Cain & Henriksen, 2013; Zydney et al., 2019) report the experiences of implementing collaborative activities in hybrid settings. Nonetheless, these studies roughly addressed the teachers' orchestration load in collaborative and hybrid learning environments and the students' perceptions. In summary, this study aims to understand the factors contributing to orchestration load, and the students' perceptions toward collaborative hybrid settings, by implementing a jigsaw collaborative pattern (Hernández-Leo et al., 2010) hybridly, in a university course with 2 teachers and 67 students. The overarching research questions guiding this work are.

RQ1. Which are the factors contributing to teacher orchestration load in collaborative learning activities within hybrid environments?

RQ2. Which are the students' perceptions toward collaborative activities within hybrid learning environments?

The remainder of this paper is as follows. Section 2 describes the theoretical background and the related work reported in the literature. Next, Section 3 describes the research design including the study context, the participants and the data sources. Section 4 presents the results, and Section 5 discusses their relation with the posed research questions. Finally, Section 6 outlines the main conclusions, limitations and future work derived from this work.

2. Theoretical background

2.1. Hybrid learning

The evolution of technologies (*e.g.*, smartphones), the appearance of new educational models (*e.g.*, distance learning) and the worldwide circumstances (*e.g.*, Covid-19) have derived into rich and complex technology-mediated scenarios that combine different teaching and learning modalities that originally were conceived as opposed: formal-informal, online-onsite, individual-collaborative, professional-academic, etc. (Gil et al., 2022). Posing such dichotomies into the same learning scenario is nowadays denoted as 'hybrid learning' (Gil et al., 2022). The highest popularity of hybrid learning was reached in 2020,[1] likely derived by the Covid-19 lockdown although the term started to be used since the early 2000's.

While different types of hybridity have been identified (Nørgård, 2021), the one involving online and onsite students simultaneously in the same learning situation is receiving special interest (Raes et al., 2020). Authors regularly refer to this modality as *Blended Synchronous Learning* (Bower et al., 2014; Huang et al., 2017; Zydney et al., 2019), *Synchronous Hybrid Learning* (Raes et al., 2020; Bülow, 2022), or *Hybrid Classroom* (Morgan et al., 2022).

Although the concept of "blended learning" also involves the onsite-online dichotomy, "synchronous blended learning" requires a synchrony between the onsite and online students, both of them following and completing the class learning activities at the same time. Similarly, while "HyFlex models" let students choose to attend online synchronously, face-to-face, or asynchronously through recordings (Beatty, 2007; Heilporn & Lakhal, 2021), "synchronous hybrid learning" involves activities that must be completed by both

[1] Google Trends: https://trends.google.com/trends/explore?date=today%205-y&q=%22hybrid%20learning%22.

onsite and online students synchronously. From now onward, in this paper *Hybrid Learning* will refer to this concrete type of hybridity. The Gartner Report on 'Top Technology Trends in Higher Education for 2022' pointed to 'hybrid classrooms' as an emerging trend in 2021 that has grown even more intense in 2022, emphasizing the need for equipping these classrooms with technology (Morgan et al., 2022).

A recent systematic literature review about the available empirical evidence on hybrid learning, aimed at formulating benefits, challenges and design principles (Raes et al., 2020). The results show that most studies are rather preliminary, being exploratory and describing students' experiences rather than teachers' experiences. The review points out to organizational and pedagogical benefits of this type of learning (*e.g.*, increased student enrollment rates, remote participation of externals in institutional degrees). On the other hand, the authors also identified a set of challenges such as the need of adapting the teaching approaches while maintaining comparable learning standards, or the need of better coordination due to the heavy workload demanded.

Some years ago, Bower et al. (2014) presented a cross-case study regarding synchronous hybrid learning in higher education. Most teachers and students positively assessed this new modality due to the active learning opportunities, and highlighted the importance of the technology mediating between students and teachers. However, similarly to the literature review previously mentioned, both cohorts identified similar drawbacks that should be further addressed. For instance, technology tends to limit the involvement of remote students, slowing down the face-to-face experience. Also, the study showed the high demand of teachers' load while teaching, dealing with the technology and attending onsite and online students simultaneously.

More recently, Nykvist et al. (2021) described a qualitative case study on a hybrid learning music program. The authors conducted semi-structured interviews with six teachers who pointed out three success factors for designing and implementing their courses: flexibility for students, providing them with multiple learning activities; the human element, fostering the active interaction among students and teachers; and the students' ability to be self-directed and regulated learners. Lohiniva and Isomöttönen (2021) performed a similar study with 11 students who participated in a hybrid learning programming course during the COVID-19 pandemic. Results indicate the importance of teachers' and peers' support, and the sense of belonging (*e.g.*, by group exercises) and self-efficacy among other factors for increasing students' motivation.

Furthermore, the challenges identified in previous studies (*e.g.*, the need to adapt the teaching approach, high teacher workload) might be aggravated when implementing active learning strategies such as those involving collaboration between students (Zydney et al., 2019). In this case, teachers should not only focus on their instruction but also on students' involvement, artifact creation and social interaction. Thus, despite the benefits of hybrid learning remarked by previous researchers, special attention has to be paid on instructors' support, classroom technology and students' interactions when using collaborative learning in hybrid settings.

2.2. *Collaborative learning in hybrid settings*

Collaboration and communication are two out of the four skills identified in all international frameworks for 21st century competencies (Voogt & Roblin, 2012), thus highlighting their importance and relevance in the current society. Therefore, technological innovations such as hybrid learning environments must support the promotion of these two skills among students. This promotion can range from a simple discussion (*e.g.*, break-out rooms) to complex collaborative scenarios (*e.g.*, jigsaw) involving groups, artifacts, roles, or flows (Aronson, 1978). This subsection describes previous studies identified in the literature dealing with synchronous hybrid learning and complex collaborative learning activities. While some of these papers were identified in the literature review conducted by Raes et al. (2020), others refer to more recent work.

Cain and Henriksen (2013); Cain et al. (2016) describe the design and orchestration decisions of two instructional teams and one individual instructor regarding three hybrid learning courses for PhD students. The three courses were hybrid but differed on the topic, the percentage of onsite and online students, the collaborative activities and the technology used: GoTo Meeting[2] and Google Hangouts.[3] The studies revealed relevant live management issues that the instructional teams had to solve such as software and hardware changes to respect of what they designed, or adjustments in the activities. The third case involved two small groups and some invited guest speakers, using the GoToMeeting software and movable cameras. The study claims for further research on instructors' support (*e.g.*, on-the-fly decisions). The experiences showed the usefulness of a technical person managing the technological issues both in the design and orchestration of the learning situations.

Zydney et al. (2019) describe three case studies implementing hybrid learning together with innovative learning strategies. Two of these cases involved a collaborative activity using WebEx[4] breakout rooms. In the first case, students were distributed homogeneously in small groups (*i.e.*, all group members were either online or onsite), and with some students getting specific roles such as technology facilitator or discussion facilitator. The goal of the activity was to foster discussion among students on a given topic. The second case involved heterogeneous groups (*i.e.*, the groups were formed by online and onsite students) that discussed on a given topic, and created a text-based artifact using the collaborative WebEx whiteboard. At the end of the session, all students joined the same online room to share the artifacts and discussion outcomes. The teachers identified several factors that should be considered for the design and implementation of these classes such as the class/group size, the available technology or the instructor's skills. Additionally, the teachers reported a cognitive overload, especially in large class sizes.

Thomson et al. (2022) revisited the 12 tips for "small group teaching" (in medical teaching) published by Steinert (1996), adapting

[2] GoTo Meeting: https://www.goto.com/meeting, last access: July 2023.
[3] Google Hangouts: https://hangouts.google.com, last access: July 2023.
[4] WebEx: https://www.webex.com/, last access: July 2023.

them to synchronous hybrid environments. Some of these tips are: planning ahead, promoting individual involvement and active participation, observing and clarifying group processes, etc. While these tips might lead to a better teaching and learning experience, they require additional teacher orchestration workload as compared with traditional face-to-face teaching. Furthermore, most revisited tips are not grounded on empirical studies, thus claiming for further empirical research to support or reject them.

As observed, these studies emphasize teachers' design and enactment decisions for collaborative learning, resulting in a higher orchestration load. In the following subsection, we narrow down the concept of orchestration load and the implications of collaborative learning on orchestration load.

2.3. Orchestration load in collaborative settings

There has been much discussion about the notion of orchestration. While Dillenbourg (2013) limits orchestration to the real-time management of learning situations, several researchers (Kollar & Fischer, 2013; Tchounikine, 2013) attempted to broaden the scope of orchestration to include the entire process from the creation of a learning situation (the learning design) to its enactment. In this study, we adopt the viewpoint of Tchounikine (2013), which considers orchestration as a combination of scripting and conducting. Scripting takes into account teachers' initial design decisions, associated constraints, and technological platforms to be used (Tchounikine, 2013). Conducting may entail several real-time activities, including the monitoring of the script progress; the modification of the script parameters (*e.g.*, the size of groups); the analysis of the students' performance and the provision of support; and other emergent activities such as debriefing, which requires the elaboration of students' productions (Dillenbourg, 2013).

A derived notion from orchestration is that of orchestration load. Although the literature provides many definitions, the main idea of this notion refers to the attentive effort (both mental and physical) teachers devote when orchestrating multiple activities and learning processes under multiple constraints (Prieto et al., 2017). Especially in the context of collaborative learning, teachers may experience a high orchestration load as they need to constantly divide their attention across multiple groups considering both social and epistemic dimensions of the learning scenario to identify potential problems. In addition, extrinsic constraints emerge from the learning situation (*e.g.*, limited time available to finish the activity, latecomers that demand regrouping of students, space in which learning occurs), teacher supporting tools, teachers' pedagogical intentions can have an impact on instructors' orchestration load (Prieto et al., 2017). On the one hand, the complexity of the factors that contribute to the orchestration load and the lack of robust instruments available to measure this notion in authentic learning scenarios has prompted most existing studies to refer to this concept as a high-level concept or to ignore studying it in detail as a significant component of orchestration (Prieto et al., 2017). On the other hand, it is crucial to investigate how orchestration load originates in authentic learning settings in order to reduce the elements that lead to the growing workloads of the teachers (Amarasinghe et al., 2022).

Among the previous studies that attempted to disentangle the facets of orchestration load is Amarasinghe et al. (2021), in which three facets of this notion were proposed: situation evaluation, goal formation, and action taking. Situation evaluation involves the monitoring and assessment of learning activities that occur at different social planes (*i.e.*, individuals, groups, and entire class) and at different epistemic dimensions, demanding certain effort (cognitive) from the side of the teachers (Amarasinghe et al., 2021). Thus, the effort required to engage in evaluating the state of the learning situation can be viewed as a facet of the orchestration load. Not only evaluating the learning situation, but teachers also need to step in and implement the necessary pedagogical actions based on their assessment of the state of the learning situation. Making decisions on the optimal course of action (goal formation) in real time and intervening with the selected set of actions (action-taking) contribute to teachers' workload and therefore to the experienced orchestration load. From a pedagogical viewpoint, it is important to optimize teachers' orchestration actions that improve students' learning gains. For instance, recalculation of student groups in real-time for collaboration (if certain students do not show up in the class) should not be seen as a burden on the side of the teachers. Rather, it is a required action that will eventually support fruitful collaboration although it may add to the workload of the teacher.

The notion of orchestration and orchestration load in co-located classroom learning scenarios has been the subject of studies conducted until recently (Prieto et al., 2017; Amarasinghe et al., 2021). On the one hand, the teacher's orchestration actions in face-to-face collaborative activities are regularly bound to one single modality. On the other hand, synchronous hybrid learning scenarios involve two modalities (*i.e.*, onsite and online students), require the mediation of technology (*i.e.*, a platform where students can complete the learning tasks virtually), and demand real-time actions to monitor, support and assess individuals and groups during the classroom.

Nevertheless, while many institutions are deploying hybrid learning situations in response to the Covid-19 pandemic, little is known about teachers' orchestration of such learning scenarios and associated workloads. For instance, lack of adequate orchestration decisions may influence collaboration among students and can eventually hamper students' fruitful interactions (*e.g.*, overwhelmed teachers may decide to create groups consisting only of online participants and onsite participants), thus creating obstacles for learning. Our expectation is that hybrid learning scenarios will contribute to increasing teachers' orchestration load because, in addition to the constraints mentioned above, teachers should consider onsite and online participants across their design, implementation and enactment. In addition, complex collaborative learning scenarios that demand teachers to split their attention across multiple groups may further increase the orchestration load that teachers experience in hybrid learning situations (*e.g.*, managing groups, attending onsite and offsite questions-requests). However, there is a lack of empirical evidence supporting such claims, and further research is required.

3. Research design

3.1. Course context

The study was conducted in a course on *Human-Computer Interaction* within the Computer Science Bachelor curriculum of a Spanish University. This course was considered appropriate for the study due to teachers' previous experience on collaborative activities. Additionally, this course regularly involves a 3-phase jigsaw activity which has been implemented for several years in face-to-face settings. Therefore, teachers can better understand the implications of moving the activity hybridly. The learning objective of this activity focuses on the principles of User-Centered Design (UCD), using the Fable of the User-Centered Designer (Travis, 2009) and their application in a practical case, *i.e.*, design a technological app to prevent queues and delays at medical centers.

A Jigsaw is a collaborative pattern that fosters students' active learning by dividing a complex task/problem into smaller issues that are distributed among group members (Aronson, 1978; Hernández-Leo et al., 2010). A 3-phase jigsaw is an example of a non-trivial collaborative activity, likely appropriate to represent all the main challenges of collaborative learning (group formation, resource distribution, etc.), thus requiring the teacher orchestration of these elements during the design, implementation and real-time management of the learning situation. The jigsaw implemented in this study was as follows.

- **Individual Phase:** Individually, students become "experts" on one out of three principles needed to address the main problem raised in the activity. To this end, teachers assign randomly one principle to each student, and provide them with related documentation. Before the next activity phase, students must read the documentation, and complete a given questionnaire. Participants were expected to complete this phase as homework within approximately 1–2 hours.
- **Expert Phase:** In this phase, students are randomly grouped with other two students who are also experts on the same principle. This phase aims to foster discussion among experts on the same principle to strengthen their knowledge. At the end, groups have to answer a shared questionnaire. This phase is expected to be completed within the 2-hour class session.
- **Jigsaw Phase:** In this phase, students are randomly grouped with other two students, who are experts on the other two principles. Students must introduce to the other group members their knowledge about the principle and solve the main problem raised in the activity. This phase is also expected to be completed within the 2-hour class session.

During the *expert* and *jigsaw* phases, students had the option of not attending physically to the classrooms, and complete the different tasks remotely, but synchronously with the rest of group members. Students were requested to inform the teachers about their preference of classroom attendance so that groups could be appropriately configured before each session. The study reported in this paper focused on the synchronous expert and jigsaw phases of the activity (one 2-hour session per phase).

Choosing the software to implement collaborative hybrid learning activities is a relevant design decision, since it may affect the teacher orchestration load. Engageli[5] is a *virtual learning environment designed to recreate high-quality, small group collaborative experiences in online and hybrid settings* (see Fig. 1). Differently from other tools, Engageli includes video-conference features, dynamic group tables, built-in collaborative documents, and provides teachers with multiple learning analytics that support the live monitoring of the activities, thus making it suitable for implementing collaborative hybrid learning activities. Additionally, Engageli permits the integration of external tools such as Google Docs within the same environment. Therefore, students can view each other, chat and talk while writing in the collaborative document. Consequently, all the course assignments were delivered as Google Docs for all groups, being later assessed by the teachers and considered for the final grade of the course.

3.2. Participants

The study involved 2 teachers and 67 students. The teachers have a PhD. in Computer Science and a broad experience in face-to-face higher education and in collaborative learning (Teacher#1: male, 33 years, 6 years of experience; Teacher#2: female, 49 years, 22 years of experience). Both teachers have no previous teaching experience in hybrid settings but they received an Engageli onboarding session before conducting the study. Teacher#1 was in charge of the expert phase while Teacher#2 was responsible of the jigsaw phase.

The students are second-year university students, mostly 19 and 20 years old, with previous experience in hybrid and online settings due to the limitations imposed by the Covid-19 pandemic in the previous years. Second-year students in this bachelor are split into two cohorts (Classroom A and Classroom B) with 40 and 27 students respectively (see Fig. 2).[6] While all students participated in the activity, 34 students (19 and 15 respectively) gave their consent to collect and analyze their perceptions towards collaborative activities in hybrid settings (RQ2). Interestingly, out of the 34 responding students, 18 always attended the sessions in person (*onsite students*), 13 always participated virtually (*online students*), and 3 participated online in one session and onsite in the other one (*online-onsite students*). Students' onboarding to the hybrid setting was facilitated through a short guide available before the learning scenario, and through a 5-min guidance at the beginning of each phase so that all students could login and practice with the main controls of Engageli.

[5] Engageli: https://www.engageli.com/, last access: July 2023.

[6] The distribution of students between Classroom A and Classroom B was performed by the administrative staff of the faculty considering two main aspects: alphabetic sorting and attendance availability.

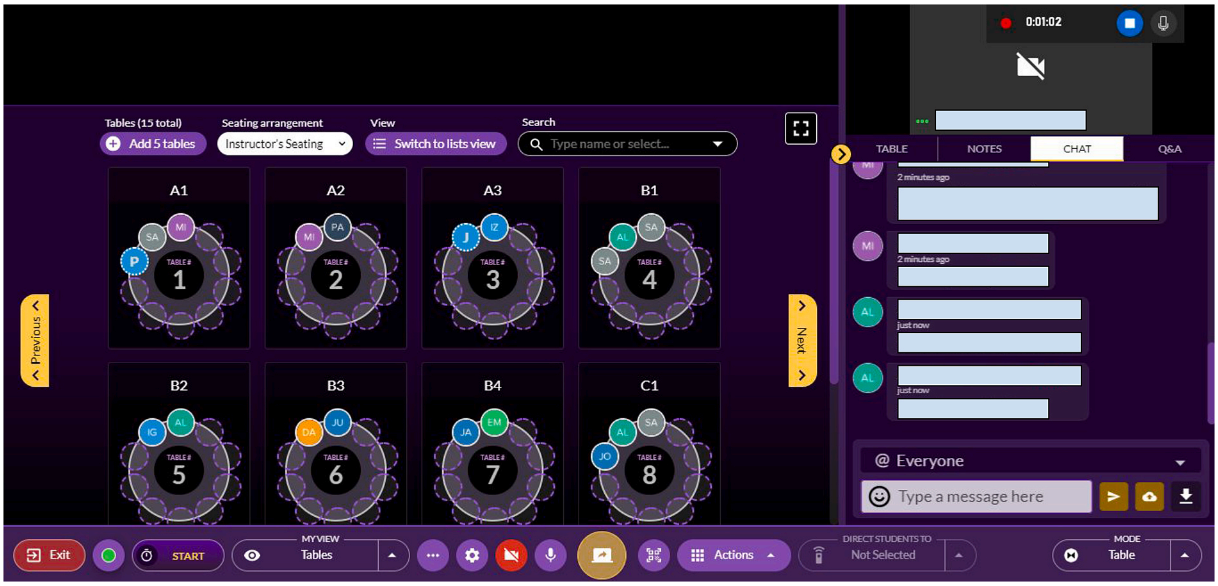

Fig. 1. Engageli table interface.

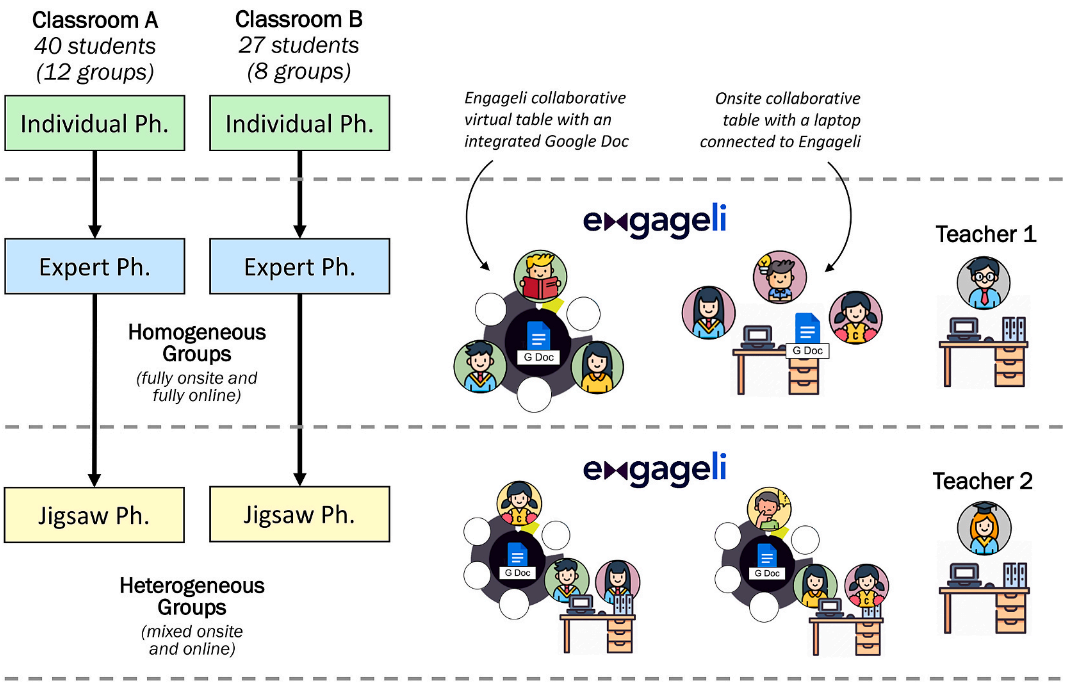

Fig. 2. Sketch of the implemented collaborative and hybrid learning scenario.

3.3. Methodology

The study follows a mixed-method research approach (Greene, 2007) in which qualitative and quantitative data were collected and triangulated. However, slightly different research designs are used for each one of the two research questions.

3.3.1. RQ1. Factors contributing to teachers' orchestration load

Regarding RQ1, the two teachers carried out the design and the setting up of the hybrid learning scenario (*e.g.*, design and configure the groups, design and configure the questionnaires in Google Docs) and their enactment (*e.g.*, manage onsite and online doubts, distribute documents, switch between classroom and table listening modes). During each session, teachers were recorded and observed by an external researcher. The researcher noted down the teachers' difficulties hindering their practice. Additionally, at the end of each session, the teachers were requested to complete the NASA-RTLX questionnaire (Hart, 2006) to measure the perceived workload of carrying out a collaborative hybrid session.

The teachers' observable behaviors (through recordings and researcher observations) during the four sessions (two sessions per teacher) were coded independently by two authors (68% initial level of agreement), following the coding scheme presented in Amarasinghe et al. (2021). Coders met to resolve coding inconsistencies and reached a full agreement. The original coding scheme consisted of codes that reflect teachers' orchestration actions at different social levels (*e.g.*, teacher-individual interactions, teacher-class interactions) as well as other teacher orchestration actions (*e.g.*, announcements to class). Apart from these codes (*etic* categories), new contextualized codes emerged during the analysis of the sessions (*emic* categories): "technical-issues" and "teacher group interaction" (see Table 1). Finally, once the jigsaw activity was finished, both teachers were interviewed simultaneously to get a more precise view of the experience and to clarify some answers given in their questionnaires.

Epistemic Network Analysis (ENA) was employed to explore whether there were differences in teachers' orchestration actions targeting, at each specific moment, either students that are exclusively onsite (*onsite actions*), students that are exclusively online (*online actions*), or students of both modalities (*hybrid actions*). ENA provides a way to study relationships between elements in coded datasets (Buckingham Shum et al., 2019; Shaffer et al., 2016). In our study, the aforementioned coded recordings and observations were used as inputs to the ENA. The nodes in epistemic networks represent the pre-specified codes (shown in Table 1). The relations (edges) are based on co-occurrences of the codes and therefore the edge weights represent the multiplicity of the co-occurrences of the codes in discourse data. In ENA, the co-occurrences are counted within a given window size, taking into account the temporality in the discourse data which is missing in aggregated frequency-based measures or the coding-and-counting approaches. Finally, ENA summarizes the arithmetic mean of the edge weights of the network model in the projection space, therefore facilitating direct comparison of different network units.

In our study, the teachers were considered as the unit of analysis. Hence, the ENA representations characterize the behavior of the teacher in a given session, and therefore the modality of the students that were the recipients of teachers' actions at every specific moment (*i.e.*, onsite, online or both) were set as the conversation variable. We followed a moving stanza window approach that accumulates connections between codes within a given window size. Following the guidelines of Siebert-Evenstone et al. (2017), we conducted a qualitative assessment of the dataset to choose the appropriate size of the window that can meaningfully capture the connections in discourse, thus enabling us to visualize how different orchestration actions relate to one another (Siebert-Evenstone et al., 2017). A window size of three was chosen for this study following the aforementioned guidelines.

3.3.2. RQ2. Students' perceptions

RQ2 explores students' perception from several perspectives: "perceived usability", "satisfaction with teacher attention", and "potential adoption". These perceptions are likely to be influenced by how teachers orchestrate the activity (this way complementing the insights provided by RQ1). In order to collect data on their perceptions, students were provided with a set of questionnaires at the end of the experience. The questionnaires included the System Usability Scale (SUS) (Brooke, 1996) to measure their perceived usability about the employed hybrid environment, the Net Promoter Score (NPS) (Reichheld, 2003) to measure their potential for adoption, and a short questionnaire that included 5-point Likert and open-ended questions to further understand students' perceptions towards hybrid learning activities (*e.g.*, the factors they liked most and least). The content validity (Fraenkel et al., 2012) of these questions was checked by two researchers. The obtained results were initially analyzed considering the 34 responding students as a whole in order to get overall trends that might complement the answers to RQ1 (*i.e.*, checking whether students' perceptions might be influenced by teachers' orchestration load). Additionally, we went a step further and explored whether students' perceptions might be affected by other two variables: the number of students per cohort (Classroom A: 40 students vs. Classroom B: 27 students); and, the modality when attending the sessions (purely onsite: 18 students, purely online: 13 students, and onsite-online: 3 students,[7] see Section 3.2).

4. Results

4.1. Factors contributing to teacher orchestration load in collaborative hybrid learning settings

4.1.1. Teachers' perceived workload using NASA-RTLX

The NASA-RTLX questionnaire measures the subjective workload of a task on a 20-point scale ranging from very low to very high (except for *Performance* ranging from "perfect" to "failure"). In this case, the tasks regarded the orchestration of the different phases of a jigsaw collaborative pattern within a hybrid learning environment. The quantitative information of the NASA-RTLX was complemented with the teachers' interview to understand the reasons for such scores.

According to the results (see Fig. 3), the average workload for scripting the sessions (*e.g.*, software configuration, group formation, document generation, etc.), and for orchestrating them (*e.g.*, class announcements, group interaction, question solving, etc.) is framed on the 3rd quartile, thus representing a medium-to-high workload for both teachers (except for the first scripting session of Teacher#1). Regarding the factors that contributed most to the design workload, the answers given by the teachers in the interview

[7] The *onsite-online* students were discarded for the statistical comparisons between the attendance modalities due to their participation in both modalities (8,82% of the total sample size).

Table 1
The coding scheme used in the study, adapted from Amarasinghe et al., 2021.

Dimension 1: Teachers' actions	
Code	Description
Teacher Individual Interaction	This code captures teachers' responses to specific questions asked by individual students.
Teacher Group Interaction	This code captures teachers' responses to questions raised by specific groups.
Teacher Class Interaction	This code captures the bidirectional interactions between teachers and the whole class (*e.g.*, teacher surveys or gives directions to the class, teacher advises how to form groups).
Announcements to Class	This code captures announcements made by the teacher to the whole class (*e.g.*, time remaining for the activity).
Teacher Perception	This code indicates teachers' attempting to gain awareness of the activity by looking into individual student devices (*e.g.*, to check students' activity participation, off-task activities etc.).
Technical Issues	This code captures technical difficulties teachers had when using Engageli (*e.g.*, teacher did not activate the microphone, teacher asked for help to distribute the digital documents).
Dimension 2: Actions' modality	
Code	**Description**
Onsite	Actions targeting onsite students or groups.
Online	Actions targeting online students or groups.
Hybrid	Actions targeting both onsite and online students or groups.

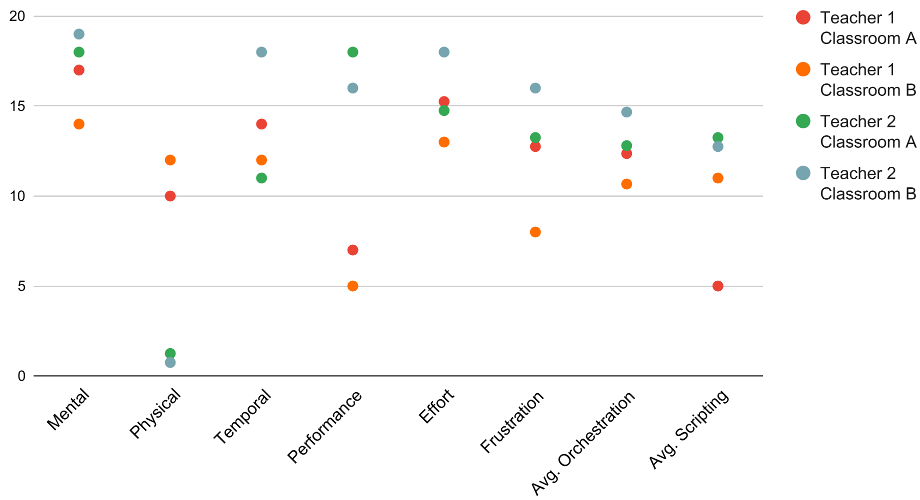

Fig. 3. Results of the NASA-RTLX questionnaires delivered to teachers after each session.

pointed to the manual creation and configuration of the group documents. Additionally, they also mentioned the fear of configuring something wrong in the platform such as the user permissions. It is worth mentioning that these issues are also likely to happen in the design of pure online situations. Nevertheless, teachers also pointed out other problems affected by the hybridity of the learning situation such as confusion with the software listening modes (*i.e.*, who can listen to who); how to address multiple questions simultaneously; how to reassign students to different groups; or the need of wearing headphones and microphone to keep track of online students.

4.1.2. Modeling teachers' orchestration actions using ENA

In order to disentangle the differences between the onsite and the online teachers' actions, we generated a difference network (see Fig. 4, left). The network was generated by subtracting the average connection strengths of teachers' onsite actions from the average connection strengths of teachers' online actions.

As it can be seen in Fig. 4 (left), the strong edges of the onsite actions are visible among *teacher.individual.interactions*, *teacher.group.interactions*, *teacher.class.interactions* and *teacher.perceptions*. Those connections may indicate that teachers' attempts to constantly gain awareness or perceive activities happening across multiple social planes (*e.g.*, individual students, groups and class level). As also indicated in Section 2.3, maintaining an overview of students' actions and progress at individual, group and class levels is a demanding task, contributing to teachers' orchestration load (Van Leeuwen et al., 2015). Moreover, the teacher's perception actions are common in these types of situations as they interact with the students in the classroom *e.g.*, diagnosing students' performance by looking into their devices or looking at the task projection. However, *announcements.to.class* was not connected to other nodes indicating either the teachers' were not in a position to make announcements, or it was not needed as they interacted with individual students and groups

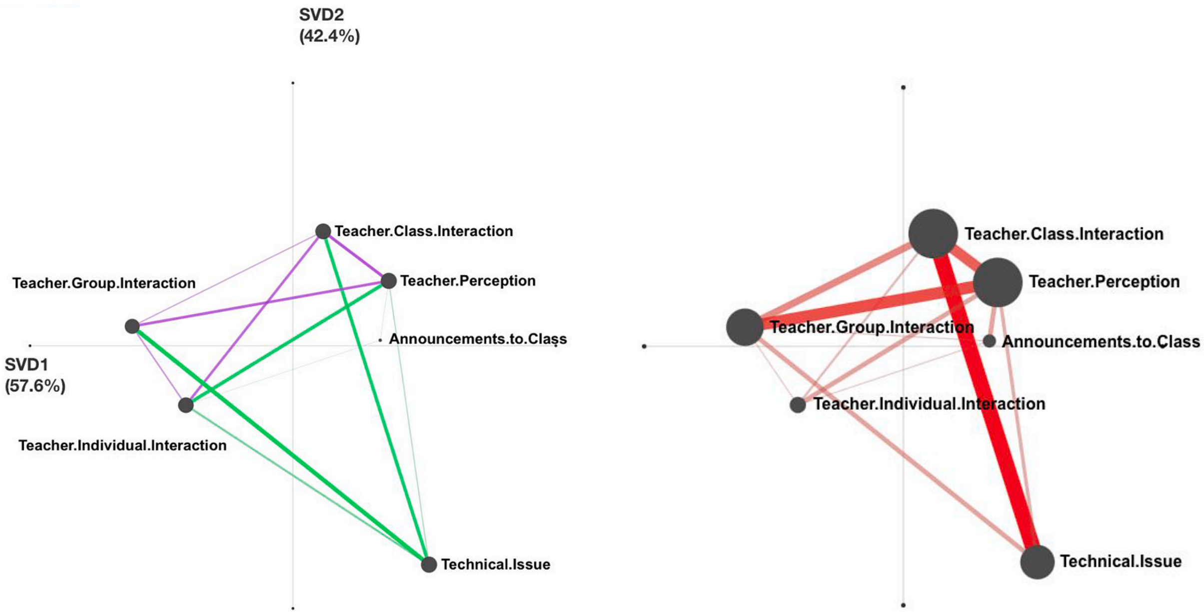

Fig. 4. Left: Difference network for onsite (in purple) and online actions (in green). Right: Mean network showing teachers' hybrid actions. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

often.

In contrast, strong co-occurrences can be observed in the online actions between *teacher.individual.interactions* and *technical.issues*, *teacher.group.interactions* and *technical.issues*, and *teacher.class.interactions* and *technical.issues*. These connections indicate that teachers focused more on the technical issues at all different social levels regarding the online actions. Conversely, those connections do not have a strong presence in the onsite actions.

Fig. 4 (right) shows the average network generated for the hybrid actions (targeting both onsite and online students simultaneously). The strongest connections of this network are between *teacher.perception* and *teacher.group.interactions* as well as between *teacher.class.interactions* and *technical.issues*. The strong connection between *teacher.perception* and *teacher.group.interactions* may indicate that teachers attempted to constantly gain awareness on group learning activities. Due to the nature of hybrid learning scenarios, dividing teachers' attention between onsite and online students was required more often (in contrast to the connections observed for the onsite actions where teacher perception is connected with individual, group and class levels). The other strong connection between *teacher.class.interactions* and *technical.issues* may indicate that teachers communicated technical issues that arose in both onsite and online actions (as some members from the same group were onsite and online simultaneously).

4.2. *Student perceptions towards CL in hybrid learning settings*

In this study, students from Classroom A and Classroom B participated in the hybrid learning situation and used the Engageli software for the first time. Some days before starting the study, participants were provided with a tool guide so they could understand the main functionalities of the software used. This subsection reports the students' perceptions towards the hybrid learning activities as described in Section 3.3.

4.2.1. *Perceived usability*

A summary of SUS final scores is presented in Table 2. The averaged SUS score obtained was 68.75 which according to Sauro (2011) is just above the average SUS score of 500 previous studies (Grade C). Nevertheless, important differences can be observed between the different cohorts (Classroom A vs. Classroom B) and the different learning modalities (onsite students vs. online students). In order to statistically compare these differences, we have performed two Mann-Whitney U tests. The Mann-Whitney *U* test[8] was selected due to the non-parametric distribution of the treatment groups regarding the response variable (SUS score), the ordinal character of the response variable, and the random condition of the treatment groups.

Regarding the differences between Classroom A and Classroom B, the Mann-Whitney *U* test resulted in a two-sided test p-value $= 0.0042$ (significant at <0.05). This indicates that we can reject the null hypothesis that distributions are equal and conclude that there is a significant difference in the perceived usability of students. Descriptive statistics indicate that the median value for Classroom A is 60 (D level of usability (Sauro, 2011)) and Classroom B is 82.5 (A level), see Fig. 5. That is to say, the difference between the median

[8] Statistical Methods. Mann-Whitney *U* Test in R: https://stat-methods.com/home/mann-whitney-u-r/, last access: July 2023.

Table 2
Results obtained from students' perceptions. *N* represents the number of participants that answered to the final questionnaire and not the number of students that participated in the activities; *Onsite x2* represents those students that were onsite at both phases; *Online x2* those that were online at both phases; and *Onsite-Online* those that were onsite in one phase and online in the other.

	N	Satisfaction with Teacher Attention (Mean | SD | NA)	SUS Score (Mean)	NPS	Tool Completeness
Classroom A	19	4.0 | 0.8 | 1	61.18 (C+)	−52.63	Use of non-additional software: 15 participants (78.95%)
Onsite ×2	12	4.1 | 0.8 | 1	59.79	−50.00	
Online ×2	5	4.4 | 0.5 | 0	66.00	−40.00	
Oniste-Online	2	3.0 | 0.0 | 0	57.50	−100.00	
Classroom B	15	4.9 | 0.5 | 0	78.33 (B+)	6.67	Use of non-additional software: 9 participants (60.00%)
Onsite ×2	6	5.0 | 0.0 | 0	71.25	0	
Online ×2	8	4.8 | 0.7 | 0	81.25	0	
Onsite-Online	1	5.0 | - | -	97.50	100	
Total	34	4.4 | 0.8 | 1	68.75 (B-)	−26.47	Use of non-additional software: 24 participants (70.59%)

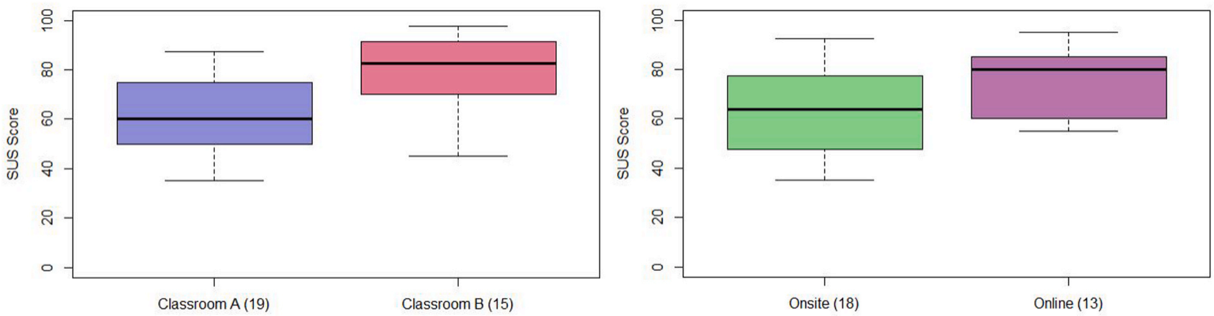

Fig. 5. Boxplot comparison regarding SUS scores.

values of each classroom is 22.5.

Regarding the differences between the learning modalities, the Mann-Whitney *U* test resulted in a two-sided test p-value = 0.05179 (significant at <0.05). This indicates a tendency towards statistical difference between the onsite students (Median = 63.75, IQR = 28.12) and the online students (Median = 80, IQR = 25), having a difference between the median values of 16.25 points.

Therefore, Classroom B, as compared with Classroom A (*i.e.*, smaller class size), perceived Engageli more useable. Similarly, the online students, as compared with the onsite students, perceived much useable Engageli. Further studies are needed to understand the reasons for such differences.

4.2.2. Satisfaction with teacher attention

The student satisfaction regarding the attention received by the teachers was measured in the final questionnaire.[9] The overall satisfaction with teacher attention was high (Mean = 4.4, SD = 0.8), thus suggesting that despite the aforementioned technical issues, the support received by the teachers was satisfactory (see Table 2). Similarly to the previous topic, and following the same reasons, we used the Mann-Whitney *U* Test to compare the results between classrooms and learning modalities.

The Mann-Whitney *U* test (Classroom A vs. Classroom B) resulted in a two-sided test p-value = 0.0014 (significant at <0.05), indicating that the null hypothesis can be rejected. Therefore, we can state that there is a statistically significant difference in the satisfaction with teacher attention of students from different cohorts. While the median value for Classroom A is 4 out of 5, the median value for Classroom B is 5 out of 5 (see Fig. 6).

The Mann-Whitney *U* test (onsite vs. online) resulted in a two-sided test p-value = 0.5089. This indicates that we cannot reject the null hypothesis (p-value >0.05) and therefore, there is not a significant difference between the satisfaction with teacher attention of students from both modalities (see Fig. 6)[10].

4.2.3. Potential adoption and tool completeness

The potential adoption of the software used was measured with the NPS (Reichheld, 2003). NPS above 0 indicates a positive potential tool adoption (Reichheld, 2003). The overall NPS was −26.47. Nonetheless, comparing the results obtained by the different cohorts we can observe important differences. While Classroom A scored negative (−52.63), Classroom B scored positive (6.67),

[9] Students were asked to rate the following statement: "I am satisfied with the attention received by the teacher when I had a question or issue" in a likert-like scale ranging from 1 (strongly disagree) to 5 (strongly agree).

[10] One possible reason for such a lack of significance is the use of a 5-point scale given the observed ceiling effect in both distributions

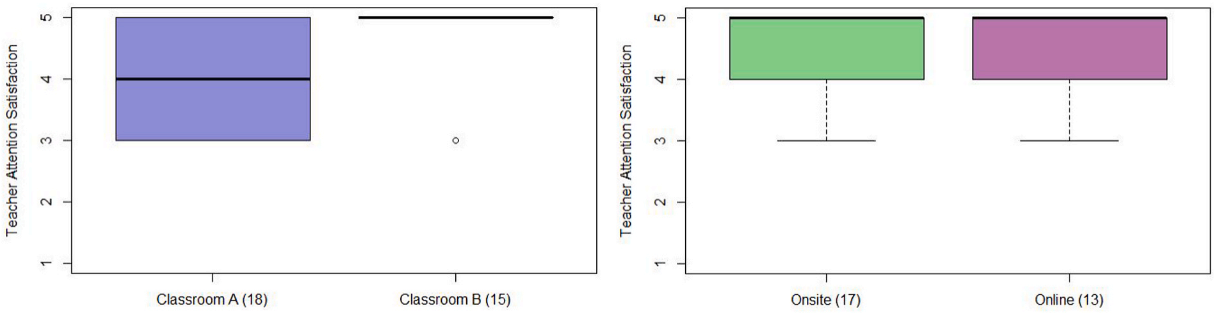

Fig. 6. Boxplot comparison regarding satisfaction with teacher attention.

having a higher number of promoters than detractors. This result suggests that potential adoption of collaborative hybrid activities is likely to be influenced by the size of the classroom.

The features that were most liked by the students were: (1) the distribution of students in tables; (2) the possibility of group editing documents within the same interface; and (3) it is easy to learn and use. The two most repeated features that might hinder their adoption as reported by the students are: (1) the limited features when documents are shared (*e.g.*, students are fixed to tables and cannot move to other tables); and (2) the students' confusion to understand who can listen to them (*i.e.*, the group or the whole classroom), a feature also pointed out by the teachers.

In order to understand whether Engageli was complete enough for this collaborative hybrid activity, we asked students in the final questionnaire to state whether they used any other external software and why. In general, students found Engageli very complete and did not need additional external tools (70.59%, see Table 2). However, some students experienced problems with the microphone forcing them (and other group members) to use the Engageli integrated chat, or Whatsapp. Additionally, other students preferred to use external software such as the Google Drive chat, or Discord as they are more familiar with them.

5. Discussion

We aim to answer our first RQ based on the results obtained through the NASA-RTLX questionnaire, the ENA and the teachers' post-interview. The NASA-RTLX results revealed that both teachers perceived the mental demand and the effort as factors contributing most to the orchestration workload of the collaborative hybrid activity. In this context, one of the findings of the systematic literature review of Raes et al. (2020) states that heavy mental load, also referred to as *hyper-zoom* or *hyper-focus* (Ørngreen et al., 2015), has already been identified as one pedagogical challenge of synchronous hybrid settings. The ENA results (see Fig. 4) showed that teachers carried out many actions to monitor and evaluate the onsite students at different social planes (*i.e.*, individuals, groups and the whole class). Evaluating learning activities occurring at different social planes is known to increase teachers' orchestration load in onsite learning scenarios (Amarasinghe et al., 2021). Considering the actions targeted to online students, ENA indicated that teachers focused on solving technical issues at all social levels. Finally, considering the hybrid modality (actions targeted to onsite and online students simultaneously), it was observed that teachers attempted to divide their attention across onsite and online students and were involved in solving technical issues. To sum up, the findings from ENA indicated that solving technical issues becomes important when synchronous online students are involved in collaboration. Guiding students to use collaboration technology appropriately and solving technical problems in real-time could be a factor influencing teachers' orchestration load.

The aforementioned findings were further elaborated in teachers' post-interview responses. For instance, when online students were involved in group learning activities, teachers found it difficult to know which students were connected and actively contributing within the groups (*e.g.*, Teacher#2: "I was not aware about what was happening in each group"). In this regard, both teachers pointed out that although this type of activity usually requires oral communication, nowadays students tend to communicate through other channels (*e.g.*, chat messages). Therefore, they claimed real-time analytics informing about the number of messages exchanged between group participants or the contribution of each student to the shared artifact to be better aware of their participation. Additionally, as raised in the post-interview, many of the technical issues could have been addressed faster with a better preparation or a technical support team as in Cain and Henriksen (2013) and Zydney et al. (2019). Additionally, it should be interesting to explore whether the teacher orchestration load would decrease in this scenario with multiple teachers so they can divide the orchestration responsibilities.

Furthermore, teachers also emphasized the confusion with the software listening modes (*i.e.*, who can listen to who); how to address multiple questions simultaneously; how to reassign students to different groups; and the need of wearing headphones and microphone to keep track of online students. All these answers in the interview are in line with the dimensions that scored higher in the NASA-RTLX questionnaire (*i.e.*, the dimensions that contributed most to the enactment workload): mental demand (*i.e.*, how mentally demanding was the task) and effort (how hard did the teachers work to accomplish their level of performance). Improving collaboration technologies to minimize the aforementioned technical issues may facilitate teachers to regulate collaboration with relative ease, therefore contributing to decreasing their orchestration load.

On the other hand, the dimensions that contributed least to their orchestration load were the "physical demand", especially for

Teacher#2 who remained sat at her desk during the whole activity, and "performance", especially for Teacher#1 who perceived as successful the orchestration of the two sessions. Nonetheless, the subjective level of these dimensions claims for more studies analyzing these categories with multiple teachers.

Regarding RQ2, the students' perceptions toward collaborative hybrid learning activities are likely to be influenced by how the teacher orchestrated the activities. In this study, we measured such perceptions according to (1) the satisfaction with teacher attention when students had questions or issues; (2) the potential adoption of this new learning model, and (3) the perceived usability of the software used. In general, the average satisfaction with teacher attention was high, the perceived usability of the software, acceptable, and the potential for adoption low.

Interestingly, we observed important differences between the two Classrooms, likely derived from their different sizes (12 vs. 8 groups). The smaller Classroom reported significantly better perceptions regarding the three aforementioned factors as compared with the larger one. These results are in line with Zydney et al. (2019), showing that the smaller the classroom is, the better perception the students have. Further studies should be carried out to understand whether this better perception from the smaller classroom is due to the lower number of orchestration actions demanded from the less number groups, and therefore, teachers have more availability to attend students questions. We also observed that online students perceived statistically significantly better the usability of the tool as compared with the onsite ones. One potential reason might be that the students were the ones who decided whether attend physically or virtually to the sessions, and the more conventional ones preferred to be onsite, being more reluctant to changes and/or use new software in their daily practice, thus rating lower the usability of Engageli.

Finally, one challenge of synchronous learning scenarios identified by Raes et al. (2020) is to maximize the social presence of online students so they feel included within the class. Surprisingly, this problem of feeling excluded from the class was not observed in the students' answers. In this line, the teachers expressed in the interview that they tried to remain seated with the headphones on to keep track of online students at every moment. However, it might be also attributed to the existence of small groups activities (with freedom to choose their own communication channels) or to the features of the software used. Further studies exploring the social presence of students in hybrid and collaborative learning scenarios are needed to understand the reasons for such potential feelings of inclusion.

6. Conclusions

Hybrid learning environments have become popular in recent years thanks to its flexibility for students and to the advantages for institutions (*e.g.*, courses offered worldwide). However, these environments are likely to increase the teacher orchestration load, especially when designing and setting-up collaborative activities with sophisticated technologies. This paper provides empirical evidence about the teacher orchestration load and the factors affecting such load in a jigsaw hybrid activity.

The results obtained in this study showed a medium-to-high workload of orchestrating the jigsaw hybrid activity. While some of the identified factors affecting most to the orchestration load are also common in non-hybrid collaborative activities (*e.g.*, manual creation of group documents), we also identified some factors specific from these environments (*e.g.*, managing the listening modes, monitoring groups, technical difficulties). Therefore, we claim for further studies to better understand the teacher orchestration load and to propose solutions that can help mitigate it. Additionally, we also observed that the size of the classroom and the attendance modality are factors contributing to the students' perceived usability and to the satisfaction with teacher attention, factors also closely related with the successful performance of teacher orchestration actions. All these identified factors might contribute to the development and refinement of conceptual and technological solutions supporting practitioners in the orchestration of collaborative and hybrid activities, *e.g.*, through recommendations when configuring the number of groups and the group size of the activities. It is worth mentioning that this study focused on the technological aspects of teacher orchestration, and further studies would be needed to understand such orchestration from other points of view such as the emotional communication or the classroom culture and climate.

This study has some limitations. First, the study relies on teachers' and students' perceptions, and on researchers' codification. Therefore, results are dependent on the different personalities and previous experience of the participants. The use of sensor-based (*e.g.*, heart rate, electrodermal activity) and behavioral (*e.g.*, teacher movement in the classroom) data might help better understand and triangulate which are the teacher actions contributing most to such orchestration load. Additionally, another limitation is that the study only involved two teachers from the same institution, and with a similar background. Moreover, different grouping approaches were used in the different phases of the jigsaw activity (*i.e.*, homogeneous vs. heterogeneous). However, the study did not explore how the grouping strategy might influence the orchestration load since, due to organizational restrictions, this variable could not be separated from others, such as the previous experience of the students with the tool (*i.e.*, students in homogenous groups experienced the tool for the first time in the second phase of the jigsaw, while heterogeneous groups were formed for the thirds phase of the jigsaw). As future work, we plan to conduct more studies involving teachers from multiple institutions and with different backgrounds, while orchestrating different grouping approaches. Thus, we could better understand whether the results obtained in this study are generalized to other contexts.

Furthermore, although the distribution of students between the two classrooms was randomly performed by the administrative staff of the faculty, the homogeneous composition of both classrooms was assumed. Therefore, while most of the participants have a similar context (*e.g.*, age, nationality, background), a homogeneity test would be needed to confirm that the obtained results for RQ2 are solely attributed to the attendance modality and the size of the classroom.

CRediT authorship contribution statement

Alejandro Ortega-Arranz: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ishari Amarasinghe:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Alejandra Martínez-Monés:** Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Juan I. Asensio-Pérez:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Yannis Dimitriadis:** Writing – original draft, Funding acquisition, Conceptualization. **Mario Corrales-Astorgano:** Writing – original draft, Conceptualization. **Davinia Hernández-Leo:** Writing – original draft, Funding acquisition.

Data availability

The authors do not have permission to share data.

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