UNIVERSITÉ
DE GENÈVE
FACULTÉ DE PSYCHOLOGIE
ET DES SCIENCES DE L'ÉDUCATION

TEACHER ORCHESTRATION LOAD IN COLLABORATIVE LEARNING ACTIVITIES IN ROBOTICS

MEMOIRE REALISE EN VUE DE L'OBTENTION DU MASTER OF SCIENCE IN LEARNING AND TEACHING TECHNOLOGIES (MALTT)

PAR

EMMA SCHENKENBERG VAN MIEROP

DIRECTION DU MEMOIRE

Gaëlle Molinari

JURY

Morgane Chevalier

Denise Sutter Widmer

LAUSANNE 13 MAI 2024

UNIVERSITÉ
DE GENÈVE

FACULTÉ DE PSYCHOLOGIE
ET DES SCIENCES DE L'ÉDUCATION

RESUME

This study investigates teachers' orchestration tasks when orchestrating collaborative robotic activities, specifically examining the cognitive, physical, and emotional loads involved. We used an exploratory mixed-method approach to analyze teachers' tasks and the associated orchestration load during two sessions. The first session let the teachers orchestrate the collaboration themselves, and the second session employed a structured approach using the Pyramid script. Our findings reveal that Computer-Supported Collaborative Learning (CSCL) scripts benefit junior teachers by providing clear direction on facilitating student collaboration effectively. Implementing the Pyramid script notably streamlined the orchestration process. It reduced the emotional stress teachers often experience and shifted their cognitive focus toward higher-level strategic activities such as planning and effective management. This cognitive shift significantly decreased the need for immediate monitoring, thus allowing teachers to orchestrate more efficiently and with greater ease. Senior teachers experienced increases in both emotional and cognitive loads, particularly when adapting a script that they had not developed themselves. This increase can be attributed to conflicts between their internalized teaching routines and the external demands of the CSCL scripts, suggesting that while the Pyramid script offers support for junior teachers, its application among experienced teachers is limited. Our study makes a novel theoretical contribution by highlighting emotional load as an important component of orchestration load, which has been previously underexplored. Moreover, in a more practical way, we provide a detailed example of a Pyramid script tailored for robotic activities, offering a ready-to-implement resource for educators. While promising, these findings are preliminary, and further research is necessary to confirm their applicability and extend their reach in diverse educational settings.

Keywords: Teacher orchestration, Orchestration load, Computer-Supported-Collaborative-Learning, Pyramid script, Cognitive load, Physical load, Emotional load.

UNIVERSITÉ
DE GENÈVE

FACULTÉ DE PSYCHOLOGIE
ET DES SCIENCES DE L'ÉDUCATION

Déclaration sur l'honneur

et auto déclaration d'usage de l'intelligence artificielle (IA)

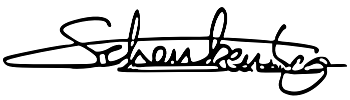
Je déclare que les conditions de réalisation de ce travail de mémoire respectent la charte d'éthique et de déontologie de l'Université de Genève. Je suis bien l'auteur-e de ce texte et atteste que toute affirmation qu'il contient et qui n'est pas le fruit de ma réflexion personnelle est attribuée à sa source ; tout passage recopié d'une autre source est en outre placé entre guillemets.

Au cours de la préparation de ce travail, j'ai utilisé DEEPL, GRAMMARLY et CHATGPT dans le but de corriger les erreurs grammaticales, de traduire les textes et pour améliorer des phrases. Après avoir utilisé ces outils, j'ai révisé et édité le contenu selon les besoins et assumes l'entière responsabilité du contenu de la publication.

Lausanne, le 13 mai 2024

Emma Schenkenberg van Mierop

Signature



Acknowlegments

I would like to thank several people whose support was invaluable during the course of my master's thesis.

Firstly, I would like to thank my supervisor, Prof. Gaëlle Molinari, for her consistent guidance and feedback. Gaëlle, your expertise and dedication to developing my research skills have considerably influenced my academic path. I have greatly valued our weekly meetings; without them, I could not have progressed and finished my thesis so quickly. I look forward to our continued collaboration in the coming years.

I would also like to thank Morgane Chevalier and Denise Sutter Widmer for accepting to be on the jury and for spending time reading my thesis. It's an honour to present my work to both of you.

Additionally, my gratitude goes to the two teachers who agreed to participate in this study. Thank you for opening your classroom doors to me and for being so motivated throughout this project.

To all my Concordia colleagues, thank you for these two great years of shared stress and laughter. A special thanks to Ana and Marco, who have been my biggest support during these years and have made the MALTT program so enjoyable. Our shared projects, along with our board games and escape games breaks, were not only fun but also vital for keeping our spirits high. I'm grateful to have had you both as friends during this Master.

To my parents, thank you for always believing in me, even when I doubted myself and never thought I could get so far in life. Thank you for your encouragement and financial support. Ik hou van jullie!

Last but not least, a very special thanks to my amazing boyfriend, Kiru, for his patience and constant support. Kiru, your encouragement and calm presence have been a great help during the busiest times. Thank you for believing in me and making me smile, even when I am stressed. I couldn't even fathom everything we overcame together this year. I love you so much. Thanks for always being by my side.

Thank you all for being there; this master's thesis would not have been possible without all of you.

Contents

1 Introduction **7**

2 Literature review **9**
- 2.1 What do we mean by teacher orchestration ? . . . 9
  - 2.1.1 Orchestration in pedagogy . . . 9
  - 2.1.2 Orchestration in didactics . . . 10
  - 2.1.3 Orchestration in CSCL . . . 10
- 2.2 What do we mean by teacher orchestration load? . . . 15
  - 2.2.1 Cognitive load . . . 17
  - 2.2.2 Physical load . . . 18
  - 2.2.3 Workload . . . 18
  - 2.2.4 Emotional load . . . 19
- 2.3 Educational robotics . . . 21
- 2.4 Collaboration . . . 22
- 2.5 CSCL scripts . . . 22

3 Research questions and hypotheses **24**

4 Method **24**
- 4.1 Population . . . 25
- 4.2 Procedure . . . 26
- 4.3 Material . . . 28
  - 4.3.1 Collaborative learning task . . . 28
  - 4.3.2 Orchestration task questionnaire . . . 28
  - 4.3.3 Orchestration load questionnaire . . . 29
- 4.4 Data analysis method . . . 32

5 Results **32**
- 5.1 Teachers' orchestration tasks . . . 32
- 5.2 Teachers' orchestration load . . . 36
  - 5.2.1 Teachers' cognitive load . . . 36
  - 5.2.2 Teachers' physical load . . . 40
  - 5.2.3 Teachers' emotional load . . . 40
- 5.3 Triangulation of orchestration data . . . 45

6 Discussion **47**
- 6.1 RQ 1: What tasks do teachers perform when orchestrating collaborative robotics tasks? . . . 48
- 6.2 RQ 2: What kind of load do teachers encounter when orchestrating collaborative robotics tasks? . . . 50
- 6.3 RQ 3: To what extent do collaborative scripts affect teacher orchestration and teacher orchestration load? . . . 51
- 6.4 Limitations of the study . . . 52
- 6.5 Areas for future research . . . 52

7 Conclusion **53**

8 Bibliography **55**

9 Appendix **61**
9.1 Demographic questionnaire 61
9.2 Stress and emotions questionnaire given before and after the sessions 65
9.3 Orchestration questionnaire 70
9.4 Pyramid script for robotic activities 77

1 Introduction

"L'orchestration, ça fait chef d'orchestre. Moi je le vois vraiment. Si ce n'est que c'est un chef d'orchestre qui est parfois passif parce que le chef d'orchestre, il donne toujours tout. Là non, il y a certains moments où on leur donne et puis les élèves jouent." (Martin, primary teacher in the canton of Vaud, 25 years of experience). [1]

The metaphor of orchestration, akin to a conductor leading an orchestra, has been frequently invoked within the field of Computer-Supported Collaborative Learning (CSCL). This analogy conceptualizes the teacher's role not merely as a dispenser of knowledge but as a facilitator guiding students towards creating knowledge (Dillenbourg et al., 2009). The teacher can employ various tools to "keep it all together", like a conductor wielding his baton (Dillenbourg, 2011, p. 47). This notion resonates in the context of digital education, particularly with the integration of technology into educational settings.

With the introduction of digital education in the Plan d'Études Romand (school curriculum for French-speaking Switzerland) in 2021, many cantons have gradually adopted digital tools into classrooms to prepare pupils for tomorrow's digital world. As a result, teachers in the canton of Vaud have benefited from several training courses throughout the year to learn how to use iPads, interactive whiteboards, and educational robots with the EduNum project. Meanwhile, students in the canton of Neuchâtel have been given an extra hour dedicated to computer science in their timetable. From the start of the school year in September 2023, 107 suitcases containing 6 Thymio robots were distributed to schools in Neuchâtel, enabling pupils to discover programming. However, collaboration becomes essential with the limited number of robots available for a class, requiring forming groups of 3 or 4 students per robot. It's not uncommon to see several students working on the same robot because of the cost of the robots (Chevalier et al., 2016). This implies that the teacher must manage the collaboration between the students in addition to any technical problems that may arise. It is, therefore, relevant to look at the orchestration load generated by collaborative robotics tasks in an exploratory approach.

While completing my Bachelor's thesis on the effects of the use of robots on algorithms, decentration, and locating in the plane skills (Schenkenberg van Mierop & Schmidt, 2022), I experienced the challenges teachers face while managing multiple groups during collaborative robotics tasks. I also encountered physical and mental exhaustion at the end of the day. This made me wonder about the cognitive, physical, and emotional load that teachers may come across while orchestrating these tasks.

Research into teachers' orchestration load (TOL) is still limited and insufficiently explored. This relatively complex and abstract concept requires in-depth analysis because of its many facets (Prieto et al., 2017). Orchestration load is the effort needed for the teacher to conduct learning tasks (Cuendet et al., 2013), while orchestration refers to how teachers simultaneously conduct various learning tasks at multiple levels in real-time (Dillenbourg & Jermann, 2010).

[1] Orchestration sounds like an orchestra conductor. I can really see that. Except that [here] it is a conductor who is sometimes passive because [normally] the orchestra conductor always gives everything. Here, no, there are certain moments when you [the teacher] give something and then the students have to play.

According to Dillenbourg and Betrancourt (2006) and Prieto et al. (2015), orchestration load comprises cognitive and physical dimensions. However, it is interesting to note that until now, research has not yet studied the emotional dimension.

Integrating Technology Enhanced Learning (TEL) into the classroom heightens teachers' challenges by adding a technical dimension to their traditional practice. A study at the École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland highlights the inherent complexity of robot management, posing a challenge to teachers. It has been established that teaching interventions focus on helping students establish links between their programs and their robots' actions in the real world (Shahmoradi et al., 2020). Four essential components of orchestration emerge from this study: (1) classroom management (management of time, groups and robots), (2) interventions designed to support a group or which interrupt the class to provide insights, (3) monitoring, which encompasses the collection of information on students and learning tools, and (4) the transmission of knowledge and instructions. The study observed 118 moments of classroom management, 106 interventions, 15 monitoring moments, and 10 knowledge or instruction contributions. Management and interventions are seen as the most important activities teachers realise in their classrooms. They can encompass managing technical failures, time, and classroom activities, as well as interventions through conducting debriefings, providing direct guidance or scaffolding. These observations allowed the researchers to identify two challenges of orchestrating robotic activities. Firstly, the increased technical complexity of the robots often proves challenging for teachers to handle. Secondly, teachers devote a substantial amount of time connecting the students' programs to the real behaviour of the robot. Finally, this study revealed gaps in educational robotics research on Teacher Orchestration Load that must be addressed.

In this master thesis, we looked at the load teachers face when orchestrating collaborative robotics activities and at the orchestration tasks carried out by teachers. A qualitative exploratory approach was chosen to address the topic and answer the questions that were raised. Two teachers, a junior and a senior teacher from Switzerland, participated in the study. Firstly, participants were given a questionnaire on their collaborative practices and use of robotics to gather information on the participants' context. In addition, before and after the experiment, the participants filled in a questionnaire on their emotions, stress, orchestration tasks, and associated load. We also conducted self-confrontation interviews with the teachers to better understand what they did and felt during the task. We aimed to understand teachers' orchestration tasks and the associated cognitive, physical and emotional load when carrying out collaborative robotics activities. The subsequent sections of this master's thesis are organized to further elaborate and contextualize these observations.

Section 2 presents a literature review on orchestration, robotics and collaborative scripts. It is followed by section 3, which proposes a research question, and then by section 4, where the method is presented. The results are developed in section 5 and discussed in section 6. Finally, section 7 sets out the main conclusions, the study's limitations and the way forward.

2 Literature review

2.1 What do we mean by teacher orchestration ?

2.1.1 Orchestration in pedagogy

Dillenbourg (2013) defines orchestration form a pedagogical standpoint as the teacher's management of simultaneous, layered activities (individual, group, and class) within various constraints (such as curriculum, assessment, time, space, energy, and safety) to achieve efficient teaching practices. The preference for the term "orchestration" over "management" is deliberate because it reflects on creating a cohesive educational setting, like an orchestra that would be in synchrony (Rothstein-Fisch & Trumbull, 2008). A cohesive educational setting is a united group that collaborates effectively, while synchrony refers to two or more events that happen simultaneously or at the same speed.

Pedagogical orchestration is a complex process rooted in a deep awareness of the educational context and learners' needs. It calls for constant re-evaluation and re-adaptation of pedagogical approaches to foster an enriching and effective learning environment.

While researchers use the term orchestration, teachers prefer terms such as "classroom management", "planning", "modelling", "scaffolding", "monitoring", "differentiation", etc. to describe their practices (see Table 1). We believe that orchestration combines all these teaching methods.

Table 1: Definitions of terms used regularly by teachers.

Classroom management	Techniques and strategies used by teachers to maintain a conducive learning environment (Jones et al., 2013).
Planning	The process by which teachers design lessons and courses.
Modelling	Demonstrating behaviours, skills or attitudes to students in order to approach a task, to solve a problem or engage in positive social interaction (Bissonnette et al., 2010).
Scaffolding	A support mechanism is used by teachers to assist students as they learn new concepts or skills by providing a temporary aid in the form of hints or instructions. They are gradually removed to foster independence (Gonulal & Loewen, 2018).
Monitoring	The continuous assessment of student progress during learning activities.
Differentiation	The practice of tailoring instructions to meet the varied learning needs, interests, and abilities of individual students (Kahn, 2017).

Specifically, in the French speaking part of Switzerland, teachers follow a classroom management framework defined by Gaudreau (2019), which encompasses five essential elements: (1) resource management, (2) establishment of clear expectations, (3) development of positive social relationships, (4) focus and engagement on the learning object and (5) management of indiscipline behaviour. We have based our definition of classroom management according to this model, as both teachers know it and use it on a daily basis.

2.1.2 Orchestration in didactics

Trouche (2003) introduces the metaphor and concept of orchestration by comparing the role of a teacher to that of an orchestra conductor. This analogy suggests that teachers have a range of responsibilities, including analyzing the curriculum to define learning objectives. This can be understood from a didactic perspective, where the activities proposed to students are designed to enable them to overcome the difficulties they encounter in their learning (Pierrot & Cerisier, 2022).

Trouche (2003) uses the concept of instrumental orchestration and defines it as the didactic management of classroom artefacts. This concept refers to how teachers manage the classroom environment to achieve educational goals, involving a planned and preemptive approach to organizing classroom space and time (Bellemain & Trouche, 2016).

Instrumental orchestration becomes noteworthy in an era where students and teachers increasingly rely on digital tools. However, despite its significance, this concept does not align with the focus of our discussion. Our emphasis remains on a pedagogical interpretation of orchestration, particularly in how teachers manage classroom activities when students engage with robots during tasks. Given our focus on collaborative learning activities, we also delved into Computer-Supported Collaborative Learning (CSCL), where researchers show a preference for the term “orchestration”. This perspective leads us to prefer the above term for its broader application to our study’s objectives.

2.1.3 Orchestration in CSCL

Class orchestration in CSCL involves coordinating supportive interventions across different activities and social levels, focusing on tasks like group formation, resource sharing, and activity planning (Dillenbourg & Betrancourt, 2006; Manathunga et al., 2017; Prieto et al., 2011). It extends to learning environments integrating activities across various contexts and media (Dillenbourg et al., 2009).

Orchestration, as described by Dillenbourg (2013) and Dillenbourg and Jermann (2010), is characterized not as a theoretical construct but as an instructional method. This approach is centered on the integration of technology within educational settings, emphasizing the facilitation of the teacher’s role in this context. Dillenbourg (2013) posits that orchestration involves the teacher’s deliberate actions to guide the learning process, including the activation, monitoring, and modification of technology-supported learning activities.

Roschelle et al. (2013) supports this view by highlighting orchestration’s focus on addressing the practical challenges of employing technology in classrooms and enhancing the teacher’s capacity to manage these challenges effectively. Hämäläinen et al. (2017) extends this understanding by arguing that teacher orchestration entails crafting diverse learning activities, varying objectives, and student choices concerning technology. It also requires the teacher to oversee multiple learning processes in the classroom and broader educational contexts.

Thus, according to Dillenbourg (2013), teacher activity in orchestration is dual-faceted: it involves both the pedagogical orchestration of classroom activities and the design of technology integration strategies. This dual focus aims to enable teachers to expand and optimize instructional design more effectively through the strategic use of technology.

The term orchestration has appeared in recent years in the field of Technology Enhanced Learning (TEL) and Computer-Supported Collaborative Learning (CSCL) (Dillenbourg & Jermann, 2010; Fischer & Dillenbourg, 2006). This is achieved through micro- and macro-scripts integrated into the design of activities and by using social interventions by a teacher (Nouri, 2014).

Despite the growing attention paid to orchestration in the technology field, this concept's theoretical and empirical exploration is relatively recent. As a result, existing research into orchestration has yet to provide in-depth and comprehensive answers. Prieto et al. (2011) mainly highlight the need for further research and knowledge about how orchestration is achieved. Furthermore, some researchers debate the orchestration metaphor of an orchestra conductor, but Dillenbourg (2013) did not use the metaphor of the orchestra conductor on purpose, and he explains that he prefers to drop this metaphor because it generates unproductive debates and rather use "orchestration" as a concept on its own. However, Kollar and Fischer (2013, p. 507) explain that "just like musical pieces, TEL environments need to be created (i.e., orchestrated), adapted (i.e., arranged) and reified (i.e., conducted)". They also add that "classroom scripts that distribute learning activities over the social planes of the classroom can be regarded as counterparts of the score in an orchestra, which demonstrates the necessity of careful lesson planning across these social levels" (Kollar & Fischer, 2013, p. 507). Though we do not participate in this debate, we find the orchestration metaphor beneficial for its simplicity in conveying concepts to teachers.

In a literature review, Prieto et al. (2011) outline a multifaceted orchestration process, encompassing the pre-class period when teachers plan their lessons and the post-class period when reflection on classroom events takes place. We believe there is one more phase. For us, orchestration involves three distinct phases: preemptive orchestration, viewed as the prescribed scenario; real-time orchestration, corresponding to the actual scenario realized in the classroom; and reflective orchestration, during which the teacher reviews and assesses the outcomes compared to the initial plan.

Prieto et al. (2011) distinguish five components, in Figure 1, underlying the orchestration of the classroom: adaptation, management, evaluation, planning and the roles of those involved.

1. **Adaptation/flexibility/intervention** refers to the process of changing and adapting planning according to the specific context of the class and the events that occur during the course. This involves managing tasks using adaptable social mechanisms or sufficiently flexible technological systems to handle these adjustments (Dillenbourg & Tchounikine, 2007).

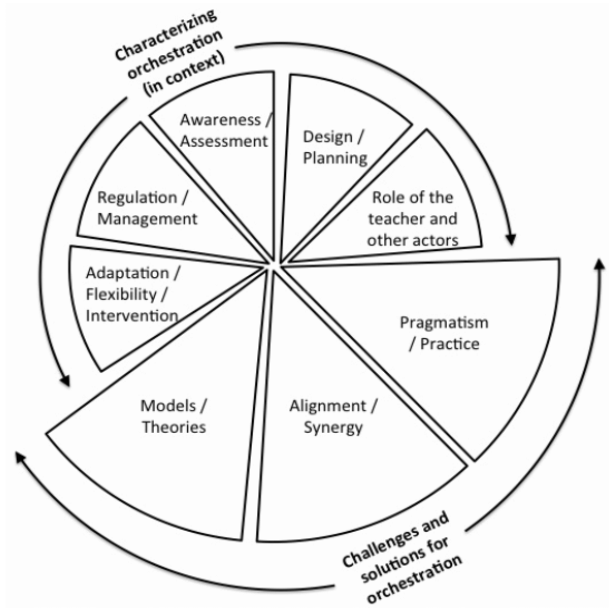


Figure 1: Representation of the conceptual framework of orchestration (Prieto et al., 2011).

2. **Management/regulation** in orchestration encompasses various aspects related to class, time, workflow and group management, as well as external or internal regulation of learning tasks (Dillenbourg et al., 2009). These processes can be carried out manually through social interaction (Dimitriadis et al., 2007) or mediated and automated by technological means.

3. **Assessment/awareness** enables formative or summative assessment, providing an overview of learners' progress towards achieving the desired learning outcomes. This approach enables learning design to be adapted accordingly. The awareness that results from formative assessment is beneficial for both learners and teachers (Watts, 2003). Given that orchestration is based on interventions responding to the classroom context and emerging events, awareness (or taking information from the flow of action) is essential in any effectively orchestrated learning scenario (Dillenbourg et al., 2009).

4. **Planning/design** can be related to educational planning and design. The preparation and implementation of orchestrated tasks generally follow an iterative process in which the teacher designs and adjusts them progressively.

5. **The roles of teachers and others** involved in orchestration include planning and carrying it out. From this perspective, the teacher's presence is essential for successful orchestration (Kennewell et al., 2008). However, the teacher's role is not limited to real-time orchestration during a task. It generally encompasses the orchestration of a task, from its design and planning to its assessment (Prieto et al., 2011). Most research on orchestration focuses mainly on the teacher's perspective (Dillenbourg et

al., 2009). This has led many proponents of learner-centred approaches to reject the concept of orchestration entirely. However, learners can still adopt these concepts, shifting the responsibility for orchestrating tasks away from teachers. We could use another metaphor, comparing the teacher to a bassist in a jazz band. They are the "side men" who keep the rhythm so the others can consistently play. As a result, students can take the lead while teachers guide their learning.

A study done by Shahmoradi et al. (2020) suggests that while the five components identified by Prieto et al. (2011) provide a universal framework, these components must be tailored to each specific learning context and, in this case, into the robotic context. Four distinct levels emerged from their analysis, which they indicated correspond to the framework: Management, Intervention, Monitoring, and Providing Knowledge and Instructions. We used 3 out of their 4 levels because we take a different stance regarding categorising "Providing Knowledge and Instructions" as a separate level. In our view, and in the Classroom management definition of Gaudreau (2019), this aspect should be integrated within the Management dimension. This difference in perspective suggests that while the study by Shahmoradi et al. (2020) investigates teachers' needs for orchestrating robotic classrooms, it may not delve deeply enough into orchestration activities from a teachers' standpoint. Additionally, despite involving three teachers with varying teaching experience levels in the study, their activities are analyzed collectively rather than distinguishing them based on their experience. We question that senior teachers might realise some orchestration activities differently than junior teachers and vice versa, pointing to a potential gap in the research.

As such, we have adopted the conceptual framework of Prieto et al. (2011) for our experiment with four out of the five components like Shahmoradi et al. (2020): (1) planning, (2) management, (3) awareness and (4) interventions and adaptations. We use the same definitions and have defined Management according to the classroom management of Gaudreau (2019). The teachers we work with are well aware of these elements and have approved our schematic representation of Figure 2. Our representation of orchestration links each component to each other. For example, if the teacher is aware that a student isn't focused on a task, they will manage the student's attention back on the task or intervene by scaffolding it.

1. **Planning** (is shown in grey in our diagram because we provided the planning to the teachers) involves designing a roadmap for instruction, setting clear objectives, and preparing resources and activities to facilitate learning. Teachers can plan the tasks, the space, the time, the interventions and the resources.

2. **Management** as defined by Gaudreau (2019) entails five components : (1) Resource management, (2) Setting clear expectations, (3) Development of positive social relations, (4) Attention and commitment to the learning object, and (5) Managing undisciplined behaviour.

3. **Awareness** involves monitoring and regulating students and groups of students as well as formative and summative assessment.

4. **Interventions and adaptations** imply unexpected events, debriefing, changing the initial planning, and scaffolding. Drawing from our bassist metaphor, this can be

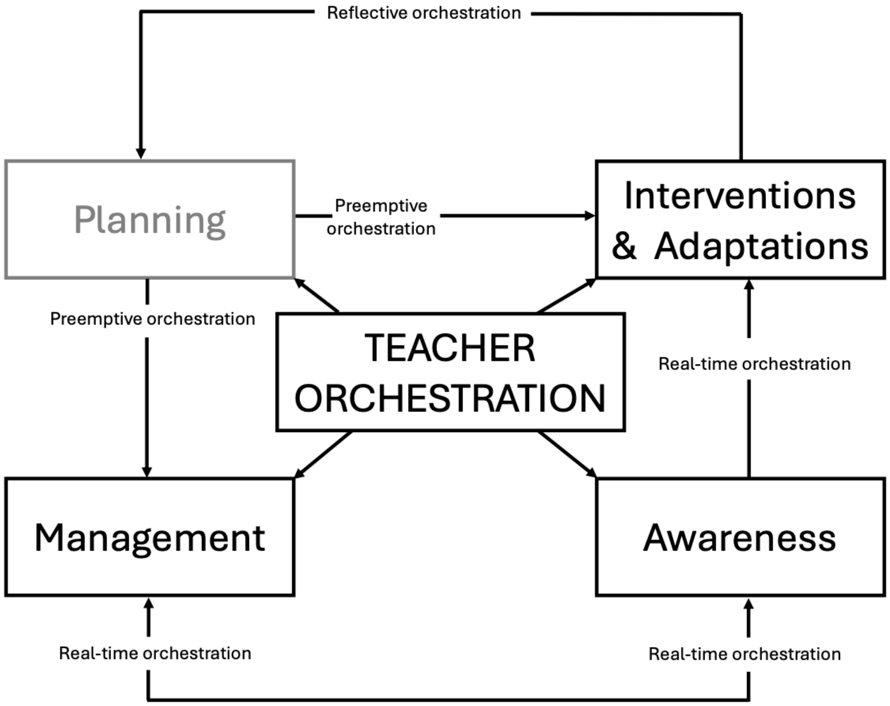


Figure 2: Proposal for a new representation of Teacher Orchestration based on the framework of Prieto et al. (2011).

> linked to improvising in a jazz band, where adaptation is essential to create a good-sounding musical piece.

In line with this vision, articulating an optimally orchestrated classroom requires management of pedagogical resources (group management, time management, technological resources), vigilance concerning groups and learners' cognition, and reactive adaptation of planning according to the classroom context. These imperatives underline the need to pay close attention to the classroom's inter-relational dynamics and temporal elements.

Dillenbourg and Jermann (2010) have developed the notion of "design for orchestration", providing a new perspective for educational technology designers. This concept draws a parallel with the well-established paradigms of usability, a field explored in the context of Human-Computer Interaction, as well as in the context of small groups in Computer-Assisted Collaboration. The "design for orchestration" approach originates from an awareness of the complexity associated with the simultaneous management of pedagogical tasks at different levels. As with usability considerations for individuals and small groups, this approach focuses on creating technological tools and resources that optimise the ability of teachers to orchestrate dynamic and collaborative learning environments effectively.

2.2 What do we mean by teacher orchestration load?

40% of Swiss teachers were in a burnout situation (Studer & Quarroz, 2017) in 2017. According to the APA Dictionary of Psychology, burnout is a:

"Physical, emotional, or mental exhaustion accompanied by decreased motivation, lowered performance, and negative attitudes toward oneself and others. It results from high performance under stress and tension, especially from extreme and prolonged physical or mental exertion or an overburdening workload, take their toll" (VandenBos, 2007, p. 150).

Several synonyms describe load, such as effort and burden, and they are often used in similar contexts.

- "Load" in cognitive psychology often refers to cognitive load, the total mental effort used in working memory (Sweller, 2010).
- "Effort" as in mental effort is the amount of cognitive work required for a task. (VandenBos, 2007). It can also be used for physical effort.
- "Burden" generally conveys a sense of heaviness and strain, often with a negative connotation. It often includes an emotional element, indicating the perceived stress associated with a task (VandenBos, 2007).

We have decided to use the term load, which is more neutral and can be quantified in the context of cognitive processes. It has been frequently used in recent literature in Technology Enhanced Learning, where "orchestration load" is defined as the effort the teacher requires to carry out learning tasks (Cuendet et al., 2013). This framework is suggested for evaluating the usability of educational technologies in the classroom, similar to how cognitive load measures usability at the individual level (Dillenbourg et al., 2018).

Currently, orchestration load is still a vague and abstract concept, but Prieto et al. (2015) claim that it has two main components visible in Figure 3:

- The physical load, such as moving within the classroom, writing on the whiteboard, or distributing handouts to students.
- The cognitive load involves evaluating classroom activities, considering different strategies, making decisions on the best ways to support the ongoing CSCL process, recalling content to be taught, monitoring students' learning progress, and determining the direction of teaching.

Researchers sometimes use the term "orchestration load" by analogy with cognitive load (Cuendet et al., 2013). Moreover, unlike cognitive load, which is often studied under controlled laboratory conditions, classroom orchestration load is difficult to simulate accurately in a laboratory. This has led most researchers to study it by observing authentic classroom conditions.

Moreover, in instances where supplementary assistance with orchestration technology is accessible, comprehending its capacity to facilitate pertinent pedagogical interventions can

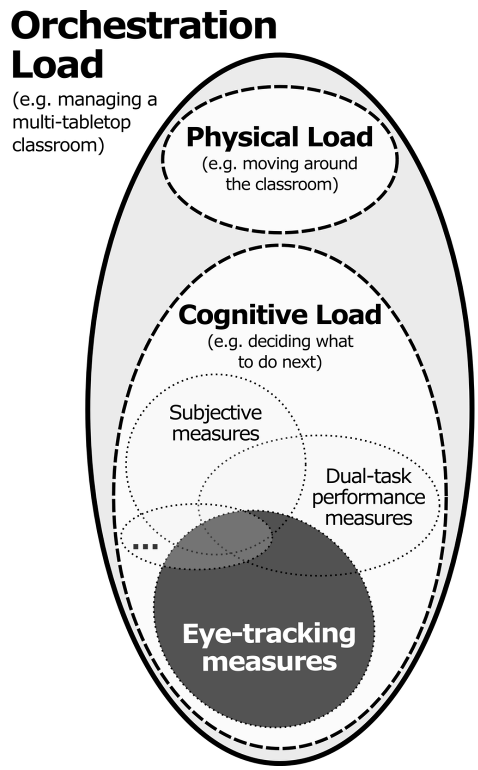


Figure 3: Representation of orchestration load (Prieto et al., 2015).

augment the cognitive load on educators (Sharples, 2013). Nonetheless, design methodologies overlooking the orchestration load for tools aimed at aiding educators result in technologies that may exacerbate rather than alleviate the management of tasks, potentially adding to the workload (Sharples, 2013).

We believe that orchestration load should also have an emotional component since teaching is an emotional profession (Frenzel et al., 2018; Frenzel et al., 2016) because of interactions with others (students, colleagues, parents, etc.) or unexpected events. These emotions can directly impact students' outcomes (Frenzel et al., 2021; Pi et al., 2022).

Frenzel et al. (2021, p. 250) created a conceptual framework that we adapted (see Figure 4). They explain that three different transmissions of emotions can happen : (1) a "direct transmission effect between teacher and student", (2) a "mediated effect on student outcomes, relationship mechanisms, nonverbal social messages, and effectiveness of instructional strategy use", and (3) a "recursive effects back from student outcomes on teacher emotions, both directly and indirectly, via teachers' appraisals of student outcomes and their correspondingly adapted instructional behaviour". We adapted the framework to include teacher orchestration load. We believe a direct transmission effect exists between student outcomes and the teacher orchestration load. Teachers' appraisals of student outcomes also mediate and recursively affect student outcomes. They all directly or indirectly affect the teacher orchestration load.

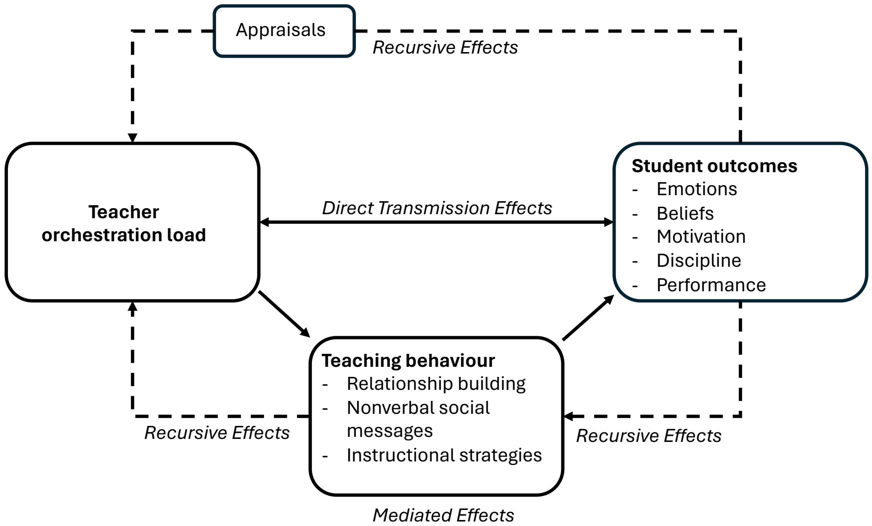


Figure 4: Conceptual framework on the links between teacher orchestration load and student outcomes adapted from Frenzel et al. (2021).

2.2.1 Cognitive load

The theory of cognitive load, developed in the 1980s by John Sweller, has become one of educational psychology's most important learning theories. This theory is particularly prized by teachers, as it provides very concrete prescriptions for instructional design.

Cognitive load theory has two main components: working memory and long-term memory (Sweller, 2011). The capacity and duration of working memory, where we consciously process information and form new knowledge, are notably restricted, particularly concerning assimilating new information (Baddeley et al., 1986; Cowan, 2001). Long-term memory securely preserves the knowledge structures that shape our behaviour over time (Prieto et al., 2015).

Cognitive load denotes the amount of working memory resources a learner necessitates to execute a cognitive task. Intrinsic load is the cognitive load specifically associated with the learning process. According to cognitive load theory, managing this load is essential to ensure it stays within the confines of the available working memory capacity (Plass & Kalyuga, 2019).

The part of the cognitive load not necessary for learning is called the extraneous load (Sweller, 2010). This load arises from cognitive tasks executed due to the particular design or choice of learning activities (Plass & Kalyuga, 2019). If the load is placed in the wrong place, it will be detrimental to the task and the learning process. For teachers, extraneous load can include complex instructional material, classroom management challenges, and technological integration. For instance, a teacher might shift their focus during a lesson to extraneous occurrences, such as a visitor entering the room or noise coming from another classroom (Feldon, 2007). Intrinsic load may become extraneous. For instance, preparing for a parent-teacher conference is appropriate during designated times but becomes a distraction during active teaching tasks. As such, the relevance of cognitive activities is highly context-dependent (Feldon, 2007). Furthermore, as teachers gain expertise, they develop more efficient information-processing schemas, requiring less mental effort (Sweller, 1999). This expertise enables teachers to manage varying levels of extraneous load without compromising their performance (Feldon, 2007).

To measure cognitive load, the literature uses subjective methods (e.g. questionnaires), objective methods (e.g. performance of a dual task), direct measures (e.g. brain imaging) or indirect measures (e.g. heart rate monitoring) (Brunken et al., 2003). However, there are several negative points to bear in mind. Firstly, because of the teachers' movement in the classroom, brain imaging is currently unreliable (Paas et al., 2003). Furthermore, physiological measures of cognitive load, such as pupillary response, are typically taken in carefully controlled lighting conditions, which is impossible in a classroom (Prieto et al., 2015). Furthermore, while subjective questionnaires are an option, they necessitate frequent interruptions during the lesson or depend on the subject's recall over an extended period. Nevertheless, this challenge can be addressed through the utilization of "stimulated recall" interviews, wherein teachers are presented with videos of the lesson (Prieto et al., 2015).

2.2.2 Physical load

Physical tasks in the workplace can be defined as repetitive tasks requiring rapid execution, involving considerable effort and specific movements. When performed frequently, these tasks can increase teachers' fatigue, making their work more complex (Kerangueven & Claudon, 2023). The physical workload associated with the teaching profession includes distributing documents and setting up the classroom.

Teachers perform a variety of physical movements throughout the day that can contribute to physical load. They often lift and carry books, materials and technology from one location to another and bend to reach or interact with students and students' materials (Gratz et al., 2002). They also walk or stand for long periods while delivering lessons and move around the classroom to facilitate group activities or to provide individual assistance. Wortman (2001) reports that these tasks demand constant interaction with active, spontaneous and impulsive children. Additionally, teachers frequently arrange desks and chairs to support different classroom configurations and activities.

Childcare workers are often prone to injuries such as sprains, bruises, and fractures (Bright & Calabro, 1999). According to several studies (Gratz & Claffey, 1996; Hostetler, 1984), a childcare worker bends 200 times per day, moves heavy equipment and furniture 32% of the time, and sits on the floor 60% of the time. As a result, teacher orchestration is heavily physically demanding.

2.2.3 Workload

While researching load in a work context, we encountered the term "workload". Every human activity involves a certain level of mental workload (Mitchell, 2000). Even the simplest physical or cognitive tasks require some mental effort, leading to a corresponding level of mental workload (Longo, 2011). Mental workload refers to the level of attention needed for decision-making (Verwey, 1990).

Workload is divided into three main areas: the amount of work and tasks to be completed; time and the specific aspects of time that are relevant; and the operator's subjective psychological experiences (Lysaght et al., 1989).

Workload is often explained using terms such as mental workload (relating to mental effort) and emotional workload (relating to excessive mental effort associated with anxiety-inducing cognitive aspects) (Cain, 2007). Gaillard (1993) argues that, although stress and workload are linked, they are not clearly defined separately. Both involve environmental demands and the individual's coping ability but come from different theoretical frameworks. Gaillard (1993) separates the ideas of workload and emotional aspects, considering them both under the control of a higher mental instance that oversees both. Essentially, the workload represents the effort this higher mental instance puts in, while emotional factors help this higher mental instance understand and manage how heavy the workload feels.

In orchestration load, the term workload isn't used much, except by Dillenbourg (2015), who defines orchestration load as encompassing two components: the workload (the energy spent on monitoring) and the cognitive load (the number of cognitive resources needed to process information) encountered by teachers (Amarasinghe et al., 2021).

The NASA Workload Index (NASA-TLX) is a commonly utilized subjective multidimensional tool for assessing perceived workload. The Human Performance Group at NASA's Ames Research Center developed it over a three-year period, involving more than 40 laboratory simulations (Hart & Staveland, 1988). Six dimensions are used: mental demand, physical demand, temporal demand, performance, effort and frustration (Miller, 2001). In the context of our study, we do not deal with workload, but we use the NASA-TLX for the mental, physical, temporal, performance, and effort dimensions to measure orchestration load. We decided to use it after it was used in a study by Amarasinghe et al. (2020) to assess teachers' orchestration load while orchestrating collaborative activities.

2.2.4 Emotional load

In the previous section, we saw that orchestration load was often equated with cognitive and physical loads. However, during their careers, teachers encounter not only cognitive load but also emotional load. Current research has not yet studied the emotional component of orchestration load.

Emotional load is defined as the "burden" resulting from the intense subjective states experienced by a person due to their responsibilities at work (Hellemans et al., 2014). There are two forms of emotional load: global emotional load and specific emotional load. Global emotional load encompasses a variety of emotional reactions linked to working conditions, such as unfavourable material, contractual, and relational aspects. Specific emotional load refers to the fact that the work in itself has an emotional dimension. Indeed, as pointed out by Van de Weerdt et al. (2017), emotional load is frequently associated with interactions with others in situations requiring the perception of others' emotions and the regulation of one's emotions to carry out one's professional tasks.

A recent study (Plass & Kalyuga, 2019) challenges separating the brain into distinct cognitive and affective regions. Pessoa (2008) argues that delineating emotion in the brain is impractical, as complex cognitive-emotional behaviours arise from intricate and dynamic interactions among brain networks. Moreover, other researchers contend that our brains similarly process emotions and cognition (LeDoux & Brown, 2017). Plass and Kalyuga (2019) examined four perspectives on emotions within cognitive load theory.

Firstly, emotions can be viewed as extrinsic cognitive load. Stress, induced by performance pressure, can occupy working memory with thoughts about the situation and performance, thereby diminishing the available working memory for task completion (Beilock et al., 2004).

Secondly, emotions can directly impact long-term memory by influencing the expansion or contraction of cognitive resources. Emotional memory storage entails consolidation, transforming fragile and susceptible memories into more stable ones (Phelps, 2004).

Thirdly, emotions may affect intrinsic cognitive load, particularly when emotion regulation is integral to learning outcomes. For instance, affective objectives may be incorporated into learning objectives (Fraser et al., 2015).

Lastly, emotions influence motivation, which entails the allocation of mental effort. Positive emotions, for instance, have been shown to enhance intrinsic motivation (Isen & Reeve, 2005).

We have preferred to separate the emotional load from the cognitive load, and we have adapted the diagram from (Prieto et al., 2014) to include emotional load. These modifications can be seen in Figure 5.

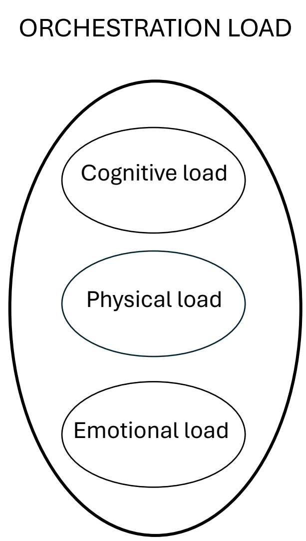


Figure 5: Representation of orchestration load, including emotional load, adapted from Prieto et al. (2015).

2.3 Educational robotics

Educational robots (ERs) are tangible educational tools embedded with actuators, sensors, and interfaces designed for direct engagement with learners, typically deployed within classroom settings (Shahmoradi et al., 2019). There are two categories of robots: social robots used as teachers to teach foreign languages, for example, and table-top robots used to develop computational thinking and physical learner-robot interaction used to teach, for example, mathematics (Khodr et al., 2020).

According to Gaudiello and Zibetti (2013) and Hsu et al. (2007), robots are real, systemic objects that can combine learning about robotics with learning through robotics, unlike virtual computers. Studies on educational robots suggest that educators are inclined to incorporate robots into teaching methodologies due to their capacity to facilitate hands-on learning experiences for students (Matarić et al., 2007), for example, by helping students decenter through manipulation (Schenkenberg van Mierop et al., 2023). Furthermore, most educators who integrate robots into their classrooms exhibit a profound intrinsic drive to enhance their teaching proficiency (Chevalier et al., 2016)).

In the realm of robotics, three distinctive traits of robots significantly influence classroom orchestration: they manifest as physical entities positioned on tables, they present as intricate technologies for educators compared to conventional classroom tools, and they are typically employed during in-person instructional sessions (Shahmoradi et al., 2019). Robotic classrooms present specific challenges for teacher orchestration, including:

- The complexity of the robots means that they need to be prepared before the lesson to ensure that they are sufficiently loaded. In addition, breakdowns of robots, which can arise unexpectedly due to technical issues, can result in time loss for students and may even necessitate significant alterations to teachers' lesson plans (Shahmoradi et al., 2019).

- Robots, although visible on students' desktops, regularly involve tasks with a screen, creating challenges of global overview. In fact, because of the distribution of information between the screen and the physical space, it can be difficult for teachers to get an overview of the class (Shahmoradi et al., 2020). Additionally, teachers may encounter challenges in monitoring students' progress, as learners employ diverse learning strategies, thereby establishing an unpredictable learning environment (Jormanainen, 2013).

- Debriefing the lesson requires teachers to be able to interrupt student tasks easily, which is not obvious when all the students are manipulating a robot. Moreover, teachers must adjust discussions based on students' input, necessitating real-time data derived from students' interactions with the robotic task (Do-Lenh et al., 2012).

In contrast to other technologies employed in classrooms, robots are often deemed expensive, prompting teachers to assign group work for students to accommodate the limited availability of robots relative to the number of students (Chevalier et al., 2016). So collaboration is essential in these activities.

2.4 Collaboration

Collaboration is defined as the joint commitment of the members of a group to achieve a common goal. They produce individually and collectively to achieve the set goal on their own. It is a democratic process in which the pooling of ideas takes precedence (Henri & Lundgren-Cayrol, 2001). Collaboration is successful when everyone is committed to building a shared representation of knowledge (Piquet, 2009).

Collaboration is an activity where participants make decisions together and contribute to creating new knowledge (Borge & White, 2016). It also implies the individual's ability to invest by pooling knowledge, skills and effort to achieve a common result (Fiore et al., 2017). Collaboration differs from cooperation in that each participant works on the same task rather than dividing the work into separate sub-tasks to be assembled later (Schneider, 2004).

Although the individual learns more and better thanks to collaboration, the reality of collaboration is not always easy to put into practice (Crook, 1995). Collaboration requires the ability to express one's thoughts clearly, to reach agreement with others, for example, on objectives, and to co-construct as a group.

2.5 CSCL scripts

Scripts arise as a method that structures team collaboration, prompting specific types of interactions known to produce learning gains (Dillenbourg & Jermann, 2010). In Computer-Supported Collaborative Learning (CSCL), group learning can be pre-emptively structured through collaboration scripts (Dillenbourg, 2002). Micro-scripts are messages that increase socio-cognitive conflict within a group. In contrast, macro-scripts combine individual and collective tasks that encourage the construction of individual opinions that are then reused in collaboration with peers (Nouri, 2014).

A collaborative script is a pedagogical scenario that students must follow when learning together. There is no "free collaboration", but there are instructions on how to form the group or how the tasks are to be carried out. Collaborative scripts often give students more responsibility (Kobbe et al., 2007), but also bring benefits such as time savings for the teacher. Collaborative Learning Flow Patterns (CLFP) serve as macro-scripts that exemplify widely accepted strategies for orchestrating collaborative learning, frequently utilized by practitioners (Hernández-Leo et al., 2006). A notable example of CLFP is Jigsaw, widely used in schools (Amarasinghe et al., 2021). Numerous studies have highlighted the efficacy of employing scripts to attain productive outcomes in collaborative learning (Radkowitsch et al., 2020; Rummel & Spada, 2005).

In our study, we use the collaborative script Pyramid CLFP, as can be seen in Figure 6.

Each dot represents a student or a group of students. The program is structured so individuals participate in a given task and independently propose an initial solution. They are then divided into small groups to review the propositions from each member and agree on a common group choice, which is then forwarded to the next level(s) where larger groups are formed, enhancing collaboration and consensus-building. At the global level, participants consolidate one or a few selected options, which are then presented to the entire class. The

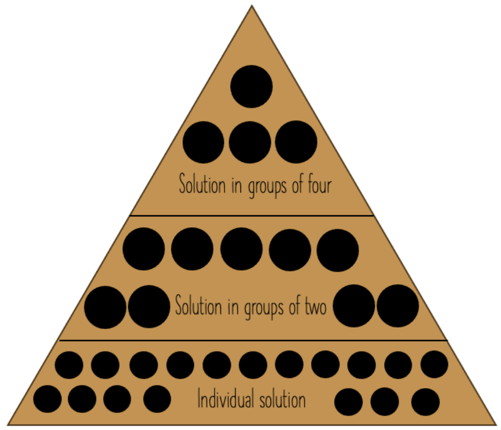


Figure 6: Representation of the Pyramid Collaborative Learning Flow Pattern script.

pyramid model promotes individual responsibility, peer interaction, and positive interdependence. It can be applied to any subject at any educational level, with or without the use of various technologies (Hernández-Leo et al., 2006).

They are then divided into small groups to discuss the options initially proposed and agree on a common group option which is propagated to the next level(s) where much larger groups are formed, enriching collaboration and consensus-building. At the global level, all participants agree on one or a few selected options, which are presented to the whole class. The pyramid model encourages individual responsibility, peer interaction and positive interdependence. This model can be applied to any subject, at any level of education, using (or not) different technologies (Hernández-Leo et al., 2006).

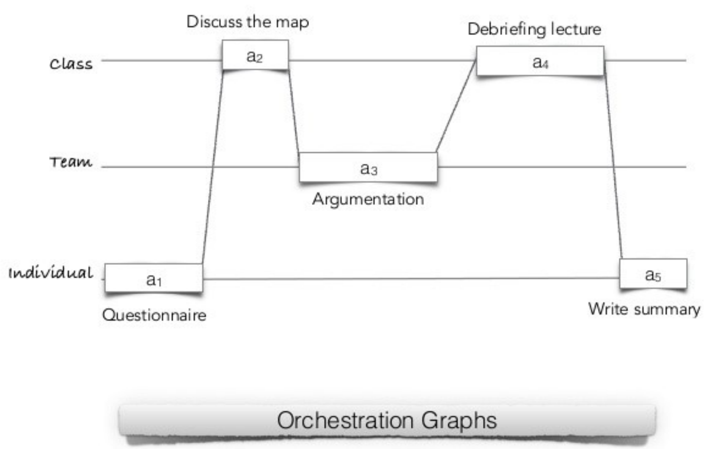


Figure 7: Orchestration graph by Dillenbourg (2015).

Dillenbourg (2015) developed Orchestration Graphs as a formal way to model CSCL scripts and similar complex learning designs; this can be seen in Figure 7. It defines a pedagogical scenario regarding learning activities at three levels: class, group and individual. The Pyramid script can be modelled through this graph because it depends on these three levels. First students try to solve a solution on their own, then they move to a team level and finally discuss their solutions with the class.

3 Research questions and hypotheses

As a reminder, we aim to understand teachers' orchestration tasks when orchestrating collaborative robotics activities and their associated orchestration load.

Based on research into orchestration by Amarasinghe et al. (2020) and Prieto et al. (2011), Prieto et al. (2015) we propose the following exploratory research questions:

1. What tasks do teachers perform when orchestrating collaborative robotics activities?
2. What kind of load do teachers encounter when orchestrating collaborative robotics activities?
3. To what extent do collaborative scripts affect teacher orchestration and teacher orchestration load?

Based on these research questions, missing literature and research from Amarasinghe et al. (2020), Frenzel et al. (2016), Prieto et al. (2011), and Shahmoradi et al. (2020) we postulate the following hypotheses:

H1: The orchestration tasks teachers are faced with are the same as in the literature, meaning planning, management, awareness and interventions.
H2: Orchestration load is divided into cognitive, physical and emotional load and differs in intensity.
H3: The orchestration tasks are different with the presence of a CSCL script, and the orchestration load is reduced compared to when the CSCL script was absent.

4 Method

A qualitative exploratory approach was chosen for this study to investigate the participants' perceptions and the context in which they occur. To collect data, observational field research was carried out with a camera. This involved recording teachers' classroom behaviour, student interactions, and on-site events. The recordings were used for semi-structured self-confrontation sessions with the participants so they could view their actions and interactions, allowing us to gather participants' reflections and explanations of their behaviour.

Previous research done by Brunken et al. (2003) and Prieto et al. (2017) has analysed objective physiological data. However, according to Dillenbourg et al. (2018) it is necessary to carry out multiple measurements to gather information on classroom orchestration. For example, recording the lesson to enable a self-confrontation session with the teacher is recommended (Prieto et al., 2017) to gather subjective data.

4.1 Population

We collected data from two primary school teachers in the cantons of Vaud and Neuchâtel in Switzerland through a questionnaire (see appendix 9.1). Before the experiment, we asked both teachers for information on their teaching experience and demographic data such as "How many years of experience do you have?" as well as data on the use of collaboration and robotics in the classroom with questions such as "What importance do you place on collaboration in your lessons" or "What are the main challenges you face when using computers in the classroom?". These results were used to create a portrait of the two teachers, which can be found in Table 2.

Table 2: Participants' data and challenges encountered when using technology and when orchestrating collaborative learning tasks.

	Martin	Pauline
Gender	Male	Female
Age	49 years old	23 years old
Teaching experience	20 years	0 years, just finished HEP (teacher training school)
Technology experience	Webmaster for 20 years	Basic knowledge of computer science
Students	20 students (6P)	19 students (7P)
Challenges with technology	Time management Tracking students' progress	Time management Tracking students' progress Technology management
Challenges in orchestrating collaborative learning tasks	Students' resistance to collaboration with certain peers	Students' resistance to collaboration with certain peers Fairness in the distribution of tasks

The first teacher, Martin (anonymized name), is 49 years old and has been teaching 5-6P classes in the canton of Vaud for over 20 years. He regularly uses digital tools in his classroom. Several times a week, his pupils carry out exercises on classroom computers and have already discovered educational robots during several activities. Martin is very experienced with technology. He has been a webmaster for 20 years and uses technology tools in his classroom daily. He currently teaches 20 pupils from grade 6P (aged 9-10). He sees the most significant challenges with using computers in the classroom as time management and tracking student progress. He has his students collaborate several times a week and considers collaboration as being important. He commented that the Pyramid CLFP collaborative script was very similar to what he did in the classroom. During math problems, students solve the problem independently, then in small groups, depending on the seating arrangement (heterogeneous groups), and repeat the exercise as a whole class. He has organised his tables into four "islands" to encourage collaboration. Each table is named after a town in the canton of Vaud, and the students from that town must work together. Nevertheless, he sees students' resistance to collaborating with certain peers as the biggest challenge in setting up collaborative tasks.

The second teacher, Pauline (anonymized name), is 23 years old and is a young teacher who has been teaching 19 pupils from grade 7P (aged 11-12) in the canton of Neuchâtel since this year. Her pupils have a period dedicated to computer science but have never programmed robots. She sees time management, technology management and tracking student progress as the biggest challenges when using technology in the classroom. She makes the students collaborate several times a year and considers collaboration as being moderately important. When she gets students to collaborate, she chooses groups randomly, lets students choose, or makes the groups mixed in levels. She considers students' resistance to collaborating with certain peers and fairness in the distribution of tasks to be the biggest challenges in setting up collaborative tasks.

4.2 Procedure

Two sessions were filmed per teacher, with a tablet and a Swivl robot (in Figure 8). It allows the teachers to be followed as they move around the classroom, keeping the focus on them. A microphone is integrated with the robot to record the teacher's voice.

Figure 8: Swivl robot with markers for tracking and voice recording.

The first session let the teacher manage the collaboration himself, and the second session scripted the collaboration using the Pyramid CLFP collaborative script. In this study, we scripted the student's activity, not the teacher's. Students' collaboration was scripted during the second session using the Pyramid script. Pupils first had to create a code on their own on paper before comparing their code in groups of two. Then, they had to compare and improve their code in groups of four and create it on the iPad. Groups of four students were required due to the limited availability of robots. Martin added another step: He brought the whole classroom together to compare their solutions and choose the best one. Teachers had to manage the group formations by putting students in pairs and groups of four.

Even though the student's collaboration was scripted, they were not the object of the study. Instead, we looked at what the teacher had done when the students had realised the scripted activity. It is needed to say that they are linked and affect each other (see Figure 9).

The study involved administering multiple questionnaires to the teachers both before and after the experiment. Teachers completed two assessments before the experiment and again immediately following its conclusion: the Stress Scale and the Emotions Scale. Additionally, after the experiment, they completed the adapted NASA-TLX specifically tailored for or-

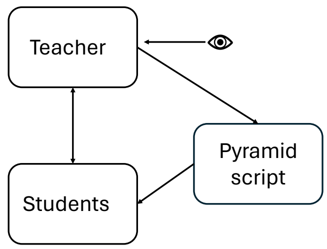


Figure 9: The object of our research: Teacher Orchestration during scripted collaborative robotics activities.

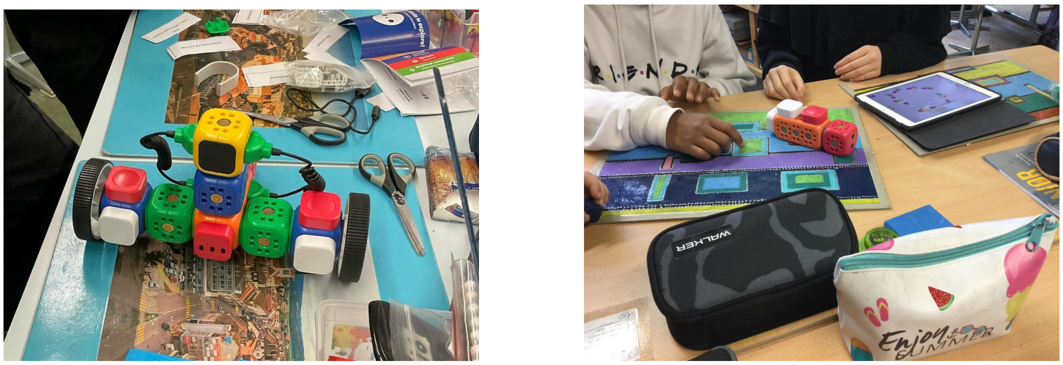
chestration tasks. These questionnaires were administered in the teachers' empty classrooms during student recess periods to ensure minimal distractions. Initially, teachers were tasked with completing the Stress and Emotion questionnaires, utilizing a rating scale ranging from 0 to 10 for stress levels and 1 to 5 for perceived emotional states. Following this, they were prompted to identify the extent of physiological stress manifestations experienced, using a scale ranging from 1 to 5. Subsequently, teachers completed a questionnaire regarding their orchestration tasks. Here, they were required to allocate a percentage across four dimensions of orchestration—planning, management, awareness, and interventions—totalling 100%. Moreover, they were instructed to indicate specific tasks within each dimension they had performed during the session. Finally, teachers completed an adapted version of the NASA-TLX for each dimension of orchestration—namely planning, management, awareness, and interventions. The full procedure of the research can be found in Table 3.

Table 3: Procedure of the research.

	Martin and Pauline
Questionnaires	Teachers completed two questionnaires: one about demographic data, teaching experience, collaboration, and robotic use, and one about their daily stress and emotional levels.
Session 1 (without script)	1. Teachers taught a 90-minute robotics lesson. Four groups of four or five students were created, each with one robot. 2. Teachers filled in a questionnaire about their orchestration load, orchestration tasks, and their stress and emotional levels.
Session 2 (with Pyramid script)	1. Teachers taught a 90-minute robotics lesson. Students worked on the problem individually, then in pairs and then in groups of four. At the last level of the Pyramid, each group got a robot. 2. Teachers completed a questionnaire about their orchestration load, orchestration tasks, stress, and emotional levels.
Self-confrontation	The self-confrontation lasted one hour, during which they watched two 5-minute videos (one from each session) and analysed the questionnaire results. Teachers were asked questions about their orchestration tasks and orchestration load afterwards.

4.3 Material

4.3.1 Collaborative learning task



Wunderkind robot   Robot and tablet application

Figure 10: Using robots in primary school classrooms.

Figure 11: Jungle mat used for the tasks.

A specific activity was created for this experiment, called the "Jungle" task. Students had to create a program for a robot that would be capable of moving, turning on its own, and making light when in front of an obstacle. Students manipulated Wunderkind robots and coded them using the Robo iPad application (Figure 10). A floor mat was explicitly created for the "Jungle" task by the Future Classroom Lab of the Haute École Pédagogique of Lausanne in Switzerland (Figure 11).

4.3.2 Orchestration task questionnaire

After the task, the teachers completed a questionnaire on the orchestration tasks they had carried out. Figure 12 shows an excerpt of the questionnaire. The full questionnaire is available in the appendix 9.3.

Awareness (prise d'information dans le flux de l'action) et régulation : .... %
o prise d'information sur l'état de la classe o prise d'information sur chaque élève o suivi et régulation

Interventions et adaptations : .... %
o évènements inattendus o débriefing o étayage o modification de la planification

Figure 12: Example of some dimensions from the orchestration tasks questionnaire completed after the collaborative learning activity.

This questionnaire was created based on the 4 dimensions according to Prieto et al. (2011): Planning, Management, Awareness and Interventions and has been discussed with the teachers, who approved the dimensions. For planning, four items were chosen : planning the activity, the material, the space and the interventions. For management, we chose the 5 components from Gaudreau (2019): Resource management (time, material, space, technology), setting clear expectations (rules of conduct, instructions, routines, expected behaviour, positive feedback), development of positive social relations (between the teacher and the students and among students), attention and commitment to the learning object (perception of the task, active engagement, differentiation, progress in the task, assessment) and managing undisciplined behaviour (preventively and reactively). For awareness, three items were chosen: awareness of the class status, awareness of each student and finally monitoring and regulation. For interventions, four items were chosen: unexpected events, debriefing, scaffolding and modification of the planning. Teachers were asked to indicate the percentage achieved for each dimension and to tick off what they had done for each dimension.

4.3.3 Orchestration load questionnaire

Cognitive and physical load questionnaire

This questionnaire was adapted from NASA-TLX. Teachers completed the NASA-TLX for each dimension of orchestration (figure 13). The full questionnaire can be found in appendix 9.3. We took 5 NASA-TLX dimensions: mental demand, physical demand, temporal demand, performance, and effort. Teachers were asked to position themselves for the five dimensions according to their feelings during the task, choosing the most relevant figure between two opposing pairs. Teachers had to fill in the adapted NASA-TLX for all four orchestration components. As a result, they had to fill out the questionnaire for planning, management, awareness and interventions.

Emotional load questionnaire

The teachers also participated in a questionnaire to record their stress from 0 to 10 before and after the collaborative learning activity (see Figure 14). The full questionnaires can be found in appendix 9.2.

AWARENESS (prise d'information) et RÉGULATION

Charge mentale : À quel degré des activités telles que penser, percevoir, décider, calculer, se souvenir, observer, chercher, etc. ont eu lieu lors de la prise d'information et de la régulation ?

Très bas — Très élevé

Charge physique : À quel degré des activités telles que pousser, tirer, tourner, contrôler, activer, etc. ont eu lieu lors de la prise d'information et de la régulation ?

Très bas — Très élevé

Pression temporelle : À quel degré avez-vous eu l'impression d'être pressé par le temps lors de la prise d'information et de la régulation ?

Très bas — Très élevé

Performance : À quel degré êtes-vous satisfait de la prise d'information et de la régulation ?

Très bas — Très élevé

Effort : L'effort à fournir pour prendre l'information et réguler était-il faible ou élevé ?

Très bas — Très élevé

Figure 13: Orchestration questionnaire adapted from NASA-TLX.

Veuillez indiquer **le stress que vous ressentez au quotidien** lorsque vous enseignez.

1. **De manière générale, lorsque j'effectue des activités collaboratives avec mes élèves je ressens du stress :**

0 1 2 3 4 5 6 7 8 9 10

Figure 14: Pre-task stress questionnaire.

For emotions, the PANAS questionnaire (Figure 15) was used to measure participants' moods and sensations using adjectives and a 5-point Likert scale measuring the intensity of each experienced emotion (1 = not at all to 5 = intensively). This scale assesses the dimensions of positive and negative affectivity, made initially in English by Watson et al. (1988) and translated by Caci et al. (2007) in French.

For stress, we have listed several physiological manifestations of stress using a Likert scale (Figure 16), that we adapted from an inventory of teachers' concerns found online ("Inventaire des préoccupations des enseignants", n.d.). We are interested in the physiological manifestations of stress since we look into the physical aspects of orchestration load and

2. Pour chacun des adjectifs, indiquez ce que vous ressentez lorsque vous effectuez des activités collaboratives avec vos élèves.

		Très peu ou pas du tout	Un peu	Moyennement	Beaucoup	Énormément
1	Stressé	1	2	3	4	5
2	Agressif	1	2	3	4	5
3	Alerte	1	2	3	4	5
4	Honteux	1	2	3	4	5
5	Inspiré	1	2	3	4	5
6	Nerveux	1	2	3	4	5
7	Déterminé	1	2	3	4	5
8	Attentif	1	2	3	4	5
9	Actif	1	2	3	4	5
10	Inquiet	1	2	3	4	5

Figure 15: Emotions felt before and after the collaborative learning tasks with robots.

MANIFESTATIONS DU STRESS

Veuillez identifier les **manifestations corporelles et physiologiques du stress** que vous ressentez lorsque vous effectuez des activités collaboratives avec vos élèves sur une échelle d'intensité de 1 (pas du tout) à 5 (beaucoup).

Je réagis au stress...

1. … en ressentant un état d'épuisement physique.	1	2	3	4	5
2. … avec une tension musculaire (cou, épaules, dos)	1	2	3	4	5
3. … avec une posture de corps rigide	1	2	3	4	5
4. … avec une sensation d'accélération du cœur.	1	2	3	4	5
5. … avec une respiration rapide.	1	2	3	4	5
6. … avec une augmentation de la transpiration	1	2	3	4	5
7. … avec une augmentation de la vitesse de parole	1	2	3	4	5
8. … avec des maux de tête	1	2	3	4	5
9. … avec des crampes d'estomac.	1	2	3	4	5
10. … avec des nausées	1	2	3	4	5
11. … avec une bouche sèche	1	2	3	4	5
12. … avec une boule dans la gorge	1	2	3	4	5
13. … avec des tremblements (mains ou autres parties du corps)	1	2	3	4	5
14. … avec une augmentation de mon agitation	1	2	3	4	5
15. … en me rongeant les ongles	1	2	3	4	5
16. … en jouant avec mes cheveux	1	2	3	4	5
17. … en tapotant des pieds	1	2	3	4	5
18. … en serrant les dents	1	2	3	4	5
19. … en touchant régulièrement mon visage	1	2	3	4	5
20. … en croisant les bras	1	2	3	4	5

Figure 16: Physiological manifestations recorded before and after the experiment.

the emotional load. We believe that these manifestations might worsen the orchestration load felt by teachers.

4.4 Data analysis method

We employed a mixed-method approach by analysing qualitative data from pre- and post-task questionnaires administered to teachers with insights garnered from self-confrontation interviews to enhance the robustness of our findings. The verbatim from the self-confrontation provided context to explain the findings from the questionnaires.

Descriptive statistics and graphs were used to compare the responses to the questionnaires from the two sessions, identifying whether there was a difference in terms of stress and emotions felt. In addition, we compared the tasks performed and the orchestration load felt between them. The orchestration tasks have been classified according to the theoretical framework of Prieto et al. (2011).

After both sessions, we chose 2 short excerpts for each teacher, one from the first session and one from the second session that we showed them during the self-confrontation. Video clips lasted approximately 5 minutes. They were chosen according to what the teacher wrote in the question "*Pourriez-vous indiquer très brièvement quels sont les moments critiques qui sont apparus lors de l'activité?*" [2]. Pauline and Martin's first session showed a moment when they tried to connect all the robots with the iPads. Pauline's second session showed her orchestrating the different groups with the Pyramid script. Martin's second session showed a clip where he had to take care of a group that was still inside the classroom while all the others were outside with their robots on the jungle mat (see Figure 11).

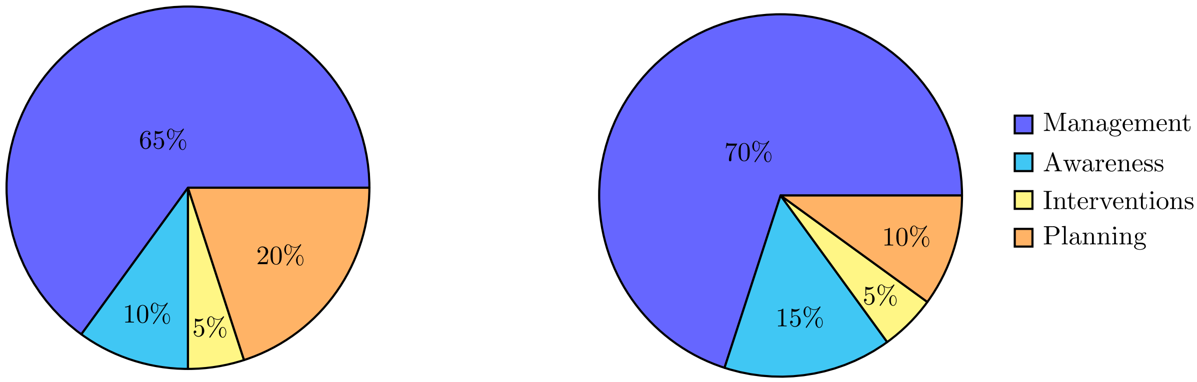
A self-confrontation was done with each teacher two weeks after the last robotic session. The self-confrontation was divided into two parts. In the first one, both teachers could express their thoughts freely after watching the video clips. They were then asked the same questions about their orchestration tasks and associated orchestration load. The second part involved analysing their questionnaire responses to better understand their answers. The self-confrontation was used to explain critical moments during the collaborative robotics session, which could have led to an increase in cognitive, physical, or emotional load. It was also used to better understand the answers given in the questionnaires. Verbatim recordings were coded depending on whether they showed cognitive load, physical load, emotional load, or orchestration activities. These codes were based on our research questions. Relevant verbatim were then connected to the relevant graph or table.

5 Results

5.1 Teachers' orchestration tasks

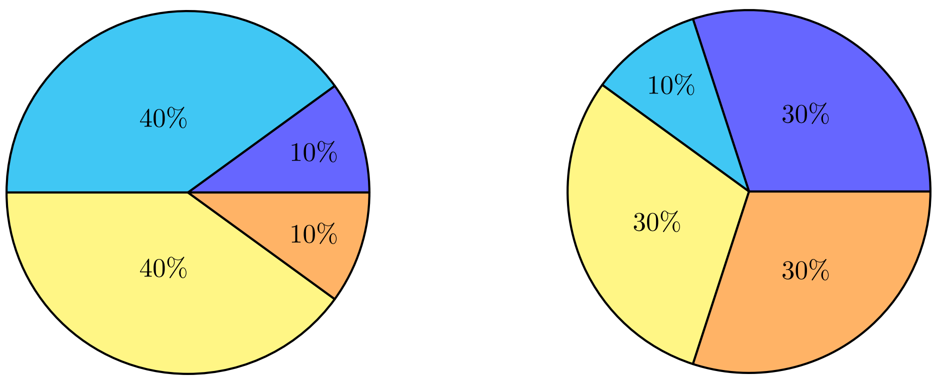
We assessed self-perceived teachers' orchestration tasks through a questionnaire. In the first session, which wasn't scripted, Martin's orchestration tasks primarily focused on classroom management (65%), as can be seen in Figure 17. In contrast, Pauline indicated realising more awareness (40%) and interventions (40%), as can be seen in Figure 18.

[2] Could you very briefly indicate which moments where critical during the activity ?



(a) Task 1 (b) Task 2

Figure 17: Martin's self-indicated percentage of orchestration tasks.



(a) Task 1 (b) Task 2

Figure 18: Pauline's self-indicated percentage of orchestration tasks.

If we look more closely at the tasks teachers reported doing during the two sessions, we notice a few differences, as can be seen in Table 4. In the first session, Martin reported not following routines, giving positive feedback to his students, or having any classroom awareness. However, if we look at the recordings, they show Martin following a pre-established routine: he uses a bell to tell students to sit down in their seats and look in his direction. This routine is very well known by the students; they immediately sit down and are quiet. Moreover, he reported not giving any positive feedback compared to the second session. This seems adequate because he left the students alone to try to code their robot while he sat back behind his desk. At the same time, in the second task, he was much more active and went to keep track of all the students, which is also reflected by the fact that he had more awareness about the class in the second session.

Pauline reported not planning the resources, classroom, and time. She also indicated that she was not managing time, resources, space, rules of conduct, expected behaviour, and relationships among students.

Table 4: Orchestration tasks done by Martin and Pauline.

	Martin		Pauline	
	Task 1	Task 2	Task 1	Task 2
Planning				
Planning the task	X	X	X	X
Planning the resources	X			X
Planning the classroom				X
Planning the interventions	X		X	
Management				
Managing time	X	X		X
Managing the resources	X	X		X
Managing the space	X	X		X
Managing the technology	X	X	X	X
Rules of conduct	X			X
Instructions	X	X	X	X
Routines		X		
Expected behaviour	X			X
Positive feedback		X	X	X
Teacher to student relation	X	X		
Student to student relation	X	X		X
Task perception	X			
Active participation	X	X	X	X
Differentiation	X	X		
Progress in the task	X	X	X	X
Assessment	X	X		
Preventive indiscipline	X			
Reactive indiscipline	X		X	X
Awareness				
Awareness about the class		X	X	X
Awareness about each student			X	
Monitoring and regulation	X	X	X	X
Interventions and adaptations				
Unexpected events			X	X
Debriefing	X	X		
Scaffolding	X	X	X	X
Changes to the planning	X		X	X

If we compare this to the second session, we notice that Martin didn't plan resources and interventions or make any changes to the planning. This can be explained by the fact that Martin had to follow the Pyramid script and wasn't as free to plan his collaboration. He also didn't manage rules of conduct, expected behaviour, perception of the task and preventive and reactive indiscipline. This can be explained by the fact that he already did it the first time and didn't see the need in doing it again since last time went well. However, this doesn't explain the higher percentage in management in the second session. Something must have required more orchestration.

In general, Martin indicated realising more orchestrating tasks than Pauline. This is especially noticeable in the first session. Martin realised 23 orchestration tasks, while Pauline only realised 14. However, in the first session, she gave some positive feedback and was aware of the class and each student. In the second session, both teachers are much closer regarding tasks realised. Martin indicated doing 18 orchestration tasks, and Pauline did 20. She manages rules of conduct, expected behaviour and reactive indiscipline. She also indicated changing the planning.

If we compare these results to the pie charts, we notice several things. Firstly, Martin realised a broader range of planning tasks in the first session, corresponding to a higher percentage, and realised more different management tasks. However, there was a higher percentage of management in the second session. For awareness, he indicated doing less in the first session, corresponding to the percentage. The indicated interventions are similar in both sessions, even though he indicated doing fewer tasks.

We noticed that Pauline realized fewer tasks in the first session than in the second one. She did less planning, especially in her indicated percentage, which tripled. She doubled her management tasks, which also tripled in percentage. She also reduced her awareness tasks, which can also be seen in the percentage, which was four times lower. She realized the same amount of interventions, which only reduced by 10%.

They both explained handling many technological issues when asked about their orchestration tasks during the self-confrontation, which required some management skills: "*Il fallait passer par tous les groupes pour au moins s'assurer que chaque groupe avait réussi à connecter le robot avec son iPad.*" (Martin) [3], and: "*J'ai l'impression d'avoir surtout réglé des problèmes technologiques.* (Pauline)" [4]. Pauline also recalled putting all the necessary tools together, giving instructions and classroom management: "*Mise en route des outils, donner les consignes, mais c'est beaucoup moins comparé au reste.* [...] *Après y'a aussi un peu de gestion.*" [5]

In the second session, which was scripted, Martin's orchestration tasks, like in the first session, primarily focused on classroom management sessions (70%), while Pauline realised management (30%), planning (30%) and interventions (30%), as can be seen in Figure 17 and in Figure 18.

Her orchestration tasks were completely transformed, she planned and managed more and required less monitoring: "*Dans le sens que le deuxième, toute la première partie, je me suis dit, ok, vous faites tout seul. Je me suis dit, bon, si ils y arrivent pas, ils y arriveront au deuxième tour. Le fait qu'il y ait plusieurs groupes, je me suis dit, on verra bien. S'ils n'ont pas compris là, c'est possible qu'au deuxième coup, ils vont y arriver, et sinon, ils réussiront le troisième. C'est pour ça que je me suis, je pense, moins mis de pression par*

[3] I had to go through all the groups to at least make sure that each group had managed to connect the robot with the iPad. (Martin)

[4] I feel like I've mostly solved technological problems. (Pauline)

[5] Setting up the tools, giving instructions, but that is much less compared to the rest. [...] There was also some classroom management.

rapport à ça. Alors que comparé au premier, comme ils étaient déjà tous ensemble, en fait, à ce stade-là, s'ils comprenaient pas, et ben, je me suis dit : ah ben... il n'y aura pas de stade supérieur pour comprendre." [6]

When asked about their orchestration tasks during the self-confrontation, Martin explained that he chose to adopt a more differentiated approach to ensure that more advanced students would be progressing more: "*Là, je me suis pris au jeu d'être de plus en plus pointu avec les élèves pour le groupe qui était tout au bout.*" [7]. He didn't want to make sure all groups were at the same level since there were only two sessions, and it wasn't assessed. He found it more important to bring the more advanced students to a higher comprehension of the concepts. On the other hand, Pauline explained that she mostly gave additional information to the students and that she did a lot of regulation: "*J'ai l'impression qu'il y a le plus de complément d'informations que j'ai donné. [...] Mais donner des infos sans donner des infos. De les aider sans donner les réponses. [...] De réguler, dans les termes HEP!*". [8]. At the Haute École Pédagogique (HEP), a teacher training school, students learn that regulation has two facets: internal regulation and external regulation. The teacher can influence the external regulation by defining the object of assessment, using feedback, observing the learning process and by adujsting the student's work. She added that she also had to manage the Pyramid script group organisation, which took longer than expected: "*Y'a aussi la formation des groupes. C'était long aussi. J'aurais pu anticiper ça en sachant dès le début qu'une élève n'était pas là.*" [9]

5.2 Teachers' orchestration load

5.2.1 Teachers' cognitive load

We assessed teachers' perceived orchestration load with the modified NASA-TLX questionnaire. We calculated the raw NASA-TLX scores for each dimension (planning, management, awareness, and interventions). This can be found in Table 5.

The first session was more demanding regarding awareness (M = 11,5 ; +2) and was the least demanding for planning (M = 9,5 ; -0,8), management (M = 10 ; -1,6) and interventions (M = 9,5 ; -3,5). Martin experienced a higher cognitive load for planning (M = 11,6 ; +2), while Pauline experienced a higher cognitive load for awareness (M = 11 ; 4,6). The lowest dimensions for Martin are management (M = 10,6 ; -2,4), awareness (M = 12 ; -0,6) and interventions (M = 9,8 ; -4,3) and the lowest dimensions for Pauline are planning (M

[6] In the sense that in the second, the whole first part, I said okay, you have to do it on your own. I thought, well, if they can't do it, they'll do it in the second round. The fact that there were several groups, I said to myself, we'll see. If they haven't figured it out yet, it's possible that they'll make it on the second round, and if not, they'll make it on the third. That's why I put less pressure on myself, I think. Compared to the first one, as they were already all together, in fact, at that stage, if they didn't understand, well, I said to myself: ah well... there won't be a next stage to understand.

[7] Here I got into a game of being more and more specific with the students for the group that was the most advanced.

[8] I have the feeling that there is more additional information that I gave. [...] But to give information without giving information. To help them without giving the answers. [...] To regulate, in HEP terminology (Swiss school of pedagogy)

[9] There was also the group formation. That took a long time. I could have anticipated knowing that a student wasn't there.

Table 5: Cognitive and physical load felt by Martin and Pauline.

	Martin		Pauline	
	task 1	task 2	task 1	task 2
Planning				
Mental demand	10	8	16	15
Physical demand	2	3	1	1
Temporal demand	15	12	4	13
Performance	14	14	9	16
Effort	17	11	7	10
Raw NASA-TLX score	11,6	9,6	7,4	11
Management				
Mental demand	14	16	18	17
Physical demand	4	3	2	1
Temporal demand	10	16	1	6
Performance	14	15	16	14
Effort	11	15	10	13
Raw NASA-TLX score	10,6	13	9,4	10,2
Awareness				
Mental demand	16	13	19	10
Physical demand	3	3	1	1
Temporal demand	14	16	14	6
Performance	12	16	5	8
Effort	15	15	16	7
Raw NASA-TLX score	12	12,6	11	6,4
Interventions and adaptations				
Mental demand	10	17	19	16
Physical demand	2	2	1	1
Temporal demand	12	16	2	8
Performance	14	17	13	18
Effort	11	16	11	17
Raw NASA-TLX score	9,8	14	9,2	12

= 7,4 ; -3,6), management (M = 9,4 ; -0,8) and interventions (M = 9,2 ; -2,8).

When asked about their cognitive load during the self confrontation, Martin explained that he was anxious before the session, because he didn't plan it, so he had to change everything to tailor it to his needs: "*La première, j'avais super peur. J'ai repris tout ton truc, j'avais tout démonté et tout ça.*" [10]. This required more planning on his part, while Pauline took the planning that was given to her and did it exactly like how it was written.

Moreover, both of them explained that the technological problems that occured required a lot of management and cognitive load: "*C'est clair que là, il y avait pas mal à gérer dans le sens qu'il fallait que les 4 groupes aient réussi cette étape pour qu'on puisse continuer. Et puis, vu que c'est pas moi qui le faisais et que je leur donnais pas un pas à pas pour*

[10] The first time, I was really scared. I'd taken your whole thing back, dismantled it and everything.

que tout le monde fasse tout au même temps, je devais intervenir dans des processus que je connaissais pas, dans le sens que je savais pas où ils en étaient. Et puis là, on a découvert l'erreur. En fait, on a changé d'iPad. Donc il y a un moment où effectivement, c'est bien d'avoir du matériel en plus. Parce que si tu dois quelque part rétroagir sur tout ce qu'ils ont fait pour retrouver là où ils se sont plantés, tu perds trop de temps." (Martin), [11] and: "*Au niveau cognitif, bah purée il faut gérer pour tout le monde et en le faisant par soi même quoi. [...] Moi, j'aurais dit, quand même, la première plus, surtout en tout cas, on peut dire, pour régler les problèmes. (Pauline)*" [12]

The second session, with the Pyramid script was more cognitively demanding for both teacher in terms of planning (M = 10,3 ; +0,8), management (M = 11,6 ; +1,6) and interventions (M = 13 ; +3,5). Awareness was the least demanding in terms of cognitive load (M = 9,5 ; -2). Martin experienced a higher cognitive load for management (M = 13 ; +2,4), for awareness (M = 12,6 ; +0,6) and for interventions (M = 14 ; +4,2), while Pauline experienced a higher cognitive load for planning (M = 11 ; +3,6), for management (M = 10,2 ; +0,8) and for interventions (M = 12 ; +2,8). Martin experienced the lowest cognitive load for planning (M = 9,6 ; -2), while Pauline experienced the lowest cognitive load for awareness (M = 6,4 ; -4,6).

When asked about their cognitive load during the self confrontation, Martin explained that because there was still one group in the classroom while all the other students were outside coding their robot on the mat, he had to make sure that everything was going well in both rooms, which required more management skills: "*C'est clair que quand t'as un groupe, que tu ne vois pas, t'as toujours cette charge supplémentaire de veiller que ça marche quand même. J'ai dû venir une ou deux fois sur ce temps-là pour voir que ça tournait.*" [13]. Moreover, he adds that the second task was more complicated to manage because of the fact that students were leading the task. Although in the first task, he experiences more cognitive load, in planning because he was leading everything, it also made it easier for him to manage the groups. While in the second task, students had to manage everything on their own, first individually, then in groups of two, and then in groups of four: "*Sur la première, c'est moi qui ai beaucoup la charge. Sur la deuxième, c'est eux. Mais du coup, la première est plus facile à gérer. Parce que c'est moi qui ai la charge, donc ils avancent à mon rythme et puis je donne les choses en découpant pour que ça avance. Donc quelque part, c'est les élèves qui me suivent. Tandis que pour la deuxième, c'est les élèves qui avancent à leur rythme. En espérant qu'on arrive au résultat attendu, ce qui est arrivé pour trois groupes sur quatre, mais ça veut dire que c'est moins confortable pour moi parce que il y a ce trou entre ce que moi je leur ai enseigné et puis le moment où ils l'auront appris et qu'ils pourront l'utiliser. Et en fait, c'est comme si tu fais tout ton travail d'enseignement mais c'est jamais garantie*

[11] Clearly, there was a lot to manage here, in the sense that all 4 groups had to have successfully completed this stage before we could continue. And since I wasn't the one doing it, and I wasn't giving them a step-by-step guide so that everyone could do everything at the same time, I had to intervene in processes I didn't know anything about, in the sense that I didn't know where they where. And then I discovered the mistake. In fact, we changed iPads. So there comes a time when it's actually good to have extra material. Because if you have to go back somewhere and retroact on everything they've done to find out where they went wrong, you're wasting too much time.

[12] At the cognitive level, you have to manage it for everyone and do it yourself. [...] Personally, I'd have said that the first one was more [demanding], mostly because I had to solve problems. (Pauline)

[13] It's clear that when you have a group that you don't see, you always have the extra burden of making sure that it's working. I had to come in once or twice during that time to make sure things were running smoothly.

qu'ils vont l'apprendre. Et donc là, c'est le moment où moi j'avais terminé mon job. Bien sûr, je pouvais encore en faire beaucoup plus. Mais il fallait que eux prennent le bébé et qu'ils s'en occupent." [14]

Pauline explained that she mostly had to take care of the organization of the groups in the second session: "*Alors cognitivement, y'a les deux, trois petits moments où il fallait un peu plus penser au niveau des groupes et puis un peu à se dire, ok j'ai vu qu'il arrivaient pas à comprendre, que c'était pas juste. Donc dire suffisamment mais pas trop pour pas leur donner les réponses, mais les guider un peu pour qu'ils comprennent ce qui était attendu d'eux. [...] Je me suis juste dis que 7 élèves ça allait faire beaucoup pour un groupe. Donc j'étais là... comment faire ? Et puis après bah je me suis dit bon bah hop allez on y va, c'est pas grave.*" [15] She adds that she also had to think a lot to know what to tell them: "*Toujours en train de réfléchir et puis un peu la même chose qu'avant, penser à ce que je vais pouvoir leur dire. Pour pouvoir les aider.*" [16]

If we conclude from the previous results, we can see that the load is distributed equally between all the orchestration dimensions in general. There is an increase in the orchestration load with the script for planning, class management and intervention tasks. The biggest increase is for interventions, and the smallest is for planning. There is a decrease in the script load, mainly in the awareness dimension. For Martin, there is an increase in the orchestration load for all the dimensions with the script, except for planning. For Pauline, there is an increase in the orchestration load for all the dimensions of the script except for awareness.

If we compare these results to the orchestration tasks realised by the teachers, we notice several things. Firstly, Martins' orchestration load was higher in the first session, coinciding with the amount of planning he realised (20 % instead of 10% in the second session). For Pauline, her orchestration load was higher for awareness, which coincides with the amount of awareness she realised (40% instead of 10%).

In the second session, Martins' orchestration load was higher for management and awareness, which coincides with the amount he managed (70% instead of 65%) and his awareness (15% instead of 10%). However, he indicated a higher load for interventions but realised the same amount in terms of tasks. Paulines' orchestration load was higher for planning and management which coincides with the amount she planned (30% instead of 10%) and the amount she managed (30% instead of 10%). However, she indicated a higher orchestration load for interventions, but realised less interventions (30% instead of 40%).

[14] On the first, I'm in charge. On the second, it's them. But as a result, the first one is easier to manage. Because I'm the one in charge, so they go at my pace and then I give them things by splitting them in smaller parts so that they move along. So in a way, it's the students who follow me. Whereas for the second, it's the students who go at their own pace. In the hope that we'll get the expected result, which we did for three groups out of four, but that means it's less comfortable for me because there's this gap between what I've taught them and when they've learned it and can use it. And in fact, it's as if you're doing all your teaching work, but there's never any guarantee that they'll learn it. So that's when my job was done. Of course, I could still do a lot more. But they had to take the baby and take care of it.

[15] So, cognitively, there were two or three little moments when we had to think a little more about the groups and then I had to say to myself, okay, I saw that they couldn't understand, that it wasn't right. So I had to say enough, but not too much, so as not to give them the answers, but to guide them a little so that they understood what was expected of them. [...] I just thought that 7 students would be a lot for one group. So there I was... how do I do it? And then I thought well, let's go, it doesn't matter.

[16] I'm always thinking, and a bit like before, thinking about what I'm going to say to them. To help them.

5.2.2 Teachers' physical load

For both teachers, the physical load was almost non-existent, as can be seen in Table 5. However, they both experienced slight differences between task 1 and task 2.

During the first task, Martin felt slightly more physical demand for management (4), but he didn't explain why. He said that he didn't have much physical load: "*Physique, il n'y a pas grand-chose à faire. Les iPads ne pas trop lourds.*" [17]

Pauline felt slightly more physical demand for management (2) in the first session. She explained that when she watched the excerpt from the first task, she realised that she was running a lot more then she tought she was: "*Au niveau physique j'avais juste un peu l'impression de courir partout. . . . mais c'est pas très physique quoi. [...] Plus là en me voyant que sur le moment.*" [18]

During session 2, Martin experienced slightly more physical demand for planning (3), but he couldn't explain why. When asked what made him feel physical load during the self-confrontation, he explained that he had to walk more between two classes, because of one group that was still inside trying to code their robot while the other groups where already outside coding their robot on the jungle mat: "*Alors, charge physique, je sais pas si on peut mettre là-dedans, le fait que eux [un groupe] sont restés en classe, parce qu'ils n'étaient pas encore à l'état [terminé de programmer], ça a compliqué un petit peu le processus. En même temps, s'ils étaient venus sur le tapis avec une machine qui n'était pas fonctionnelle, c'était pas optimum. C'est clair que quand t'as un groupe, que tu ne vois pas, t'as toujours cette charge supplémentaire de veiller que ça marche quand même.*" [19]

Pauline encountered no physical load in the second session, and she explained that she felt she was running much less: "*Physique, j'ai l'impression que ça allait. Je bouge un peu, mais je n'ai pas l'impression de courir de partout.*" [20]

5.2.3 Teachers' emotional load

We assessed several components of emotional load. Firstly, as depicted in Figure 19, we observed teacher stress level fluctuations while facilitating collaborative robotics tasks.

Before the sessions, participants were asked to estimate their daily stress levels associated with orchestrating collaborative tasks, establishing a baseline for their stress. Martin indicated having a very low stress of only 2, while Pauline indicated having a usual stress of 6.

In the first session, without the script, both teachers indicated feeling slightly more stressed than usual at the end of the first collaborative learning task. Martin indicated having a stress of 3, while Pauline indicated having a stress of 7. Both teachers increased

[17] Physically, there's not much to do. The iPads aren't too heavy.

[18] Physically, I just felt like I was running around a lot.... but it's not very physical. [...] It's more now when I see myself than at that time.

[19] So, physical load, I don't know if we can put it here, the fact that they stayed in class, because they [one group] weren't ready yet [with coding], this complicated the process a little. At the same time, if they had come to the mat with a machine that wasn't working, it wouldn't have been optimal. It's clear that when you have got a group that you can't see, you always have the extra burden of making sure that it works.

[20] Physically, I think it was fine. I move a little but don't feel like I'm running around.

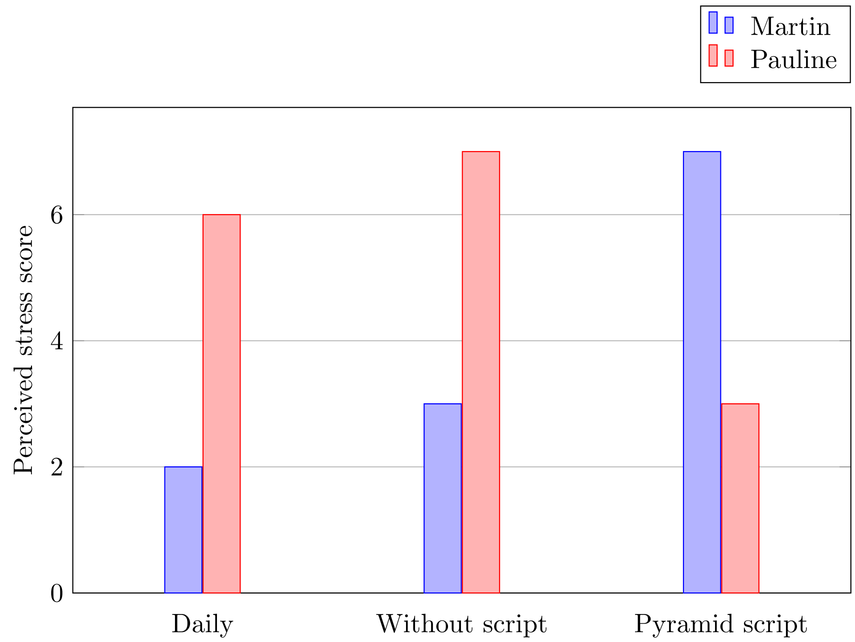


Figure 19: Stress felt by Martin and Pauline in the first collaborative robots session (without script) and in the second session (Pyramid script).

their stress levels by one, so the first session was similar in terms of stress.

During the self-confrontation interview, Pauline expressed feeling stressed during the first task, describing herself as feeling overbooked: "*Sur le moment un peu surbooké, un peu stressée.*" [21] Additionally, upon reviewing the footage, she explained feeling more stressed when watching it because she had not realized how long connecting all the robots with the iPads was taking: "*Je me sens plus stressée maintenant parce que quand on est dans le truc, il y a tellement de trucs, je me suis pas rendue compte que ça durait aussi long et qu'ils faisaient rien du tout.*" [22]

During the second task, scripted with the Pyramid script, Martin reported heightened stress levels, with a score of 7, increasing his stress by 4. In contrast, Pauline demonstrated significantly reduced stress levels, with a score of 3, reducing her stress by 4. Both teachers show completely opposite results in the second task compared to the first one.

During the self-confrontation, Martin explained that he felt more stress during the second task due to time management issues. He expressed that a third task would have been preferable as it would have allowed all students to complete the task: "*Ils ont commencé à trouver des solutions très intéressantes dix minutes avant la fin, donc voilà, le temps avait passé. Je vais pas dire que j'ai beaucoup de peine, mais pour moi le temps est surtout*

[21] At the moment, I felt a bit overbooked and a bit stressed.

[22] I feel more stressed now because when you are in the thing, there are so many things, I didn't realise how long it was taking and that they weren't doing anything.

un facteur stressant, donc j'élimine au maximum. Peut-être que ça aurait été intéressant d'avoir une troisième séance parce qu'ils y étaient presque. S'il y aurait eu cette troisième séance, j'aurais été moins stressé." [23].

Pauline, on the other hand, explained, after being asked why she experienced less stress in the second activity, replied that it was due to how the groups were scripted: "*Vraiment je pense, c'est vraiment cette histoire de groupes. Ça s'est mieux passé à cause des groupes. Le fait de savoir que même s'ils n'y arrivent pas tout de suite, ils y arriveront après à deux ou à quatre.*" [24]

Moreover, we assessed the teachers' physiological manifestations of stress and showed diverse indicators throughout both tasks, as can be seen in Table 6.

Table 6: Physiological manifestations of stress felt by Martin and Pauline.

	Martin			Pauline		
	Daily	Activity 1	Activity 2	Daily	Activity 1	Activity 2
Physical exhaustion	3	2	2	3	1	1
Muscle tension	2	2	2	3	4	1
Rigid posture	1	1	2	3	4	1
Increased heartbeat	1	1	3	3	3	1
Increased breathing	1	2	1	1	2	1
Increased sweating	2	2	1	2	1	1
Increased speed of speech	1	1	2	1	1	1
Headaches	1	1	2	2	1	1
Stomachaches	1	1	1	3	1	1
Nausea	1	1	1	3	1	1
Dry mouth	1	1	1	1	1	2
Lump in the throat	1	1	1	2	1	1
Agitation	2	1	1	1	2	1
Playing with the hair	2	1	2	1	1	1
Grit your teeth	1	1	1	4	2	1
Touch your face	1	1	3	1	4	1
Cross your arms	2	1	4	1	1	1

Under baseline conditions, Martin typically reported experiencing moderate physical exhaustion (3), slight muscle tension (2), minor increased sweating (2), and some agitation (2). Additionally, he exhibited behaviours such as playing with his hair (2) and crossing his arms (2). Under baseline conditions, Pauline typically reported feelings of physical exhaustion (3), muscle tension (3), a rigid posture (3), an elevated heartbeat (3), some sweating (2), occasional headaches (2), stomach aches (3), nausea (3), a lump in her throat (2), and

[23] They started to find some interesting solutions 10 minutes before the end, so the time ended. I don't want to say that I am struggling, but for me time is especially a stress factor, so I try to eliminate it as much as possible. Maybe it would have been interesting to have a third session because they were almost there. If there would have been a third session, I would have been less stressed.

[24] Really I think, it's really this group thing. It went better because of the groups. Knowing that even if they can't do it straight away, they will succeed later in groups of two or four.

frequently gritting her teeth (4).

During task 1, Martin experienced similar levels of physical exhaustion (2) and muscle tension (2), along with slight increases in breathing (2) and sweating (2). Pauline also exhibited physiological stress, particularly during the first task. She experienced heightened levels of muscle tension (4), a rigid posture (4), an elevated heartbeat (3), some sweating (2), minor agitation (2), gritting her teeth (2), and touching her face (4).

However, during task 2, Martin's stress responses intensified. In addition to the usual physical fatigue and muscular tension, he reported having a rigid posture (2), an elevated heartbeat (3), accelerated speech (2), and headaches (2). Furthermore, he expressed playing with his hair (2), touching his face (3), and frequently crossing his arms (4). As a result, the second task induced more physiological stress for Martin than the first task. Conversely, Pauline experienced almost no physiological stress manifestations except for a slight increase in a dry mouth sensation (2).

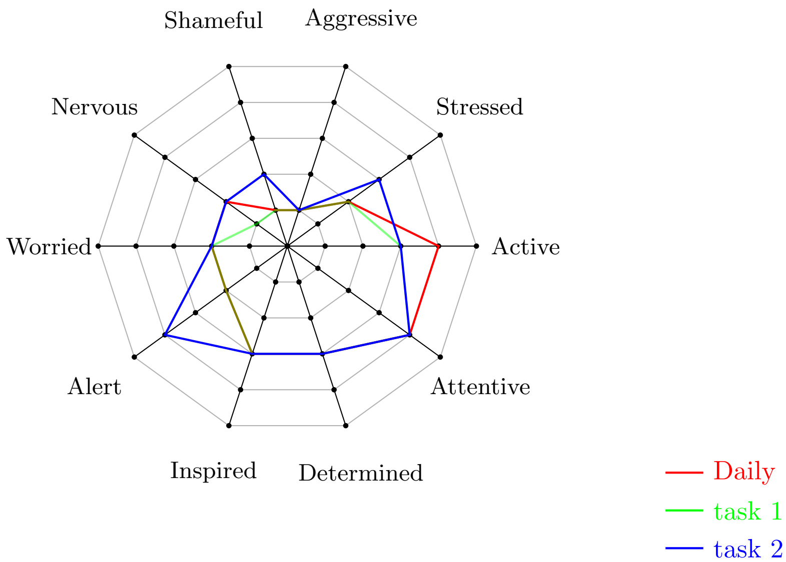
In addition, we gathered insights into participants' perceived emotions during task orchestration, establishing a baseline by considering their daily emotional experiences. This led us to create a spiderweb diagram that can be seen in Figure 20a and in Figure 20b.

During the first task, Martin encountered almost no negative emotions (Worried = 2, Nervous = 1, Shameful = 1, Aggressive = 1), while his positive emotions were high (Active = 3, Attentive = 4, Determined = 3, Inspired = 3, Alert = 2).

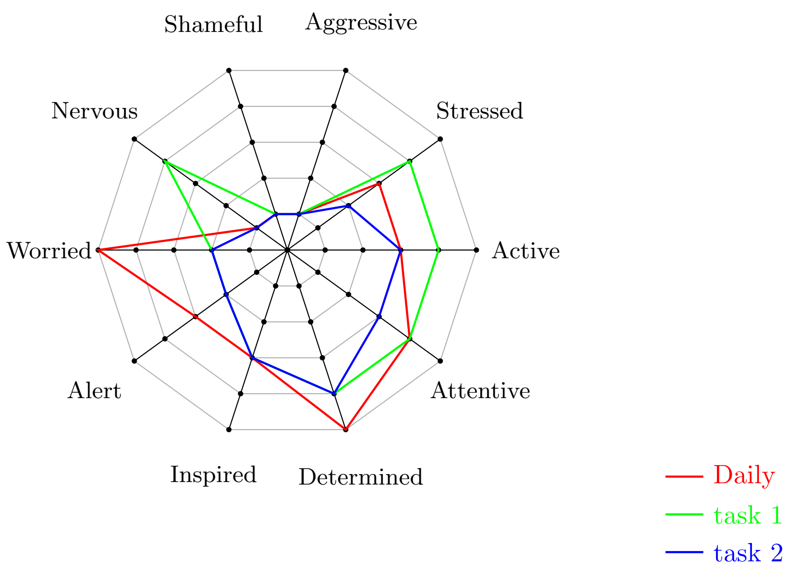
During the self confrontation, he explained that even though not all the groups were able to succeed in the task, he wasn't really concerned about it. He adds that he kept his cool so that the students would feel the same: "*J'espère que la prochaine fois, ils feront mieux. Je pense qu'il y a 20 ans, j'aurais été vachement fâché parce qu'ils avaient qu'à faire ce qu'on leur demandait. Et puis maintenant, ils apprennent. J'ai beaucoup plus de détachement, je suis moins impliqué dans leurs histoires. [...] Mes émotions réagissent avec les leurs. [...] Dans le sens que si je m'étais fâché, ils auraient réagi peut-être de manière plus carré mais ce qui n'aurait pas résolu le problème. Et puis le fait de le prendre cool, ça leur permet de le prendre cool aussi. Je pense que si je dois caractériser ce qui a le plus changé en 25 ans d'enseignement, en fait, c'est le fait que je choisis les choses qui sont importantes et qui ne le sont pas. Au début, tout est important, donc tu te bas sur tout. Après, il y a plein de choses que tu laisses passer. Par contre, les choses que tu ne laisses pas passer, tu sais pourquoi tu les laisses pas passer. Et puis, alors, tu y tiens mordicus.*" [25]

Pauline, on the other hand experienced a few higher negative emotions (Worried = 2, Nervous = 4, Shameful = 1, Aggressive = 1), and high positive emotions (Active = 4, Attentive = 4, Determined = 4, Inspired = 3, Alert = 2).

[25] I hope they do better next time. I think 20 years ago I would have gotten really angry because they just had to do what they were told. But now they're learning. I'm much more detached and less involved in their stories. [...] My emotions react with theirs. [...] In the sense that if I'd got angry, they might have reacted more squarely, but that wouldn't have solved the problem. And then the fact of taking it cool, it allows them to take it cool too. I think if I have to characterize what has changed the most in 25 years of teaching, it's actually the fact that I choose which things are important and which are not. In the beginning, everything is important, so you base yourself on everything. After that, there are plenty of things you let slide. But the things you don't let go of, you know why. And then, of course, you insist on it.



(a) Martin's emotions Spiderweb Diagram (10 Emotions, 5-Notch Scale).



(b) Pauline's emotions Spiderweb Diagram (10 Emotions, 5-Notch Scale).

Figure 20: Emotions felt daily and during tasks 1 and 2 while orchestrating collaborative tasks.

During the second session, Martin reported experiencing a slightly higher incidence of negative emotions, including feelings of shame (= 2) and nervousness (= 2). He explained that he felt disappointed that they didn't succeed because there wasn't a third time for them to be able to do the task: "*Un peu de déception pour le groupe qu'a pas réussi à aller jusqu'au bout.*" [26] He explained that the higher ashamed marker was related to the fact that he wasn't able to help them: "*Honteux, ah oui, tiens! Pour le 4ème groupe qui a pas réussi.*" [27] He adds that the second session was more complicated for him to manage because of the emotional load that he felt: "*Je dirais émotionnel parce que cognitif, il y avait moins à faire.*" [28]

Pauline encountered less negative emotions (Worried = 2, Nervous = 2, Shameful = 1, Aggressive = 1). She explained that the reason she felt less stressed, less nervous, less active, and less attentive during the second task was due to how the groups were formed: "*Je pense que c'est toujours le même fait, par rapport à ces groupes quoi.*" [29]. She never named the script as being the reason she felt less stress, but she did indicate that how the groups were formed played an important role, and even repeated it several times during the self-confrontation.

5.3 Triangulation of orchestration data

Finally, we triangulated the results from the orchestration tasks and orchestration load, which are illustrated in Figure 21 and in Figure 22.

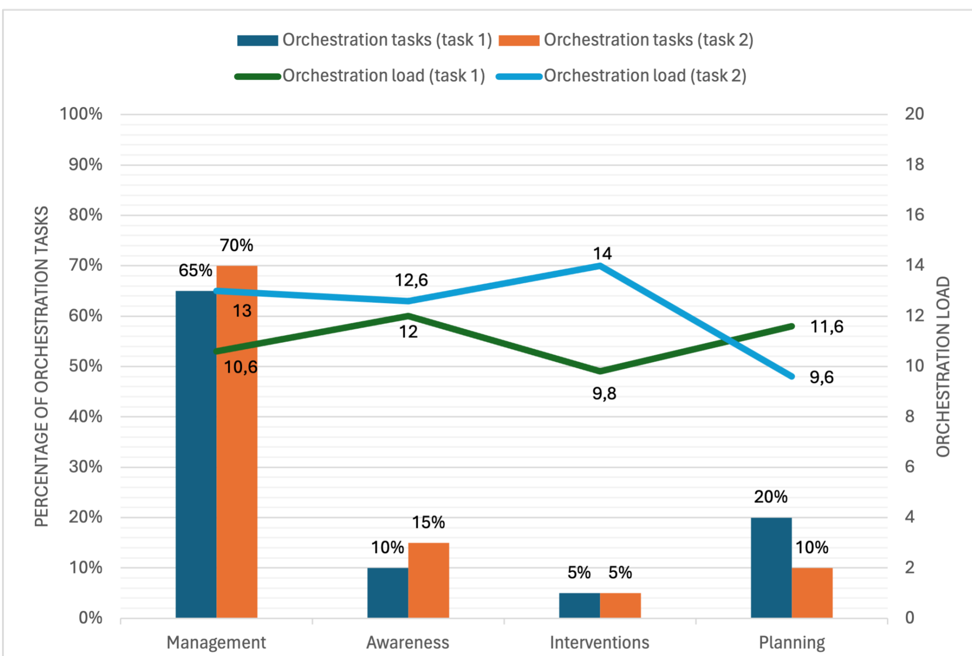


Figure 21: Martin's orchestration tasks and associated load.

[26] A bit of disappointment as well for the group who wasn't able to finish.
[27] Ashamed, ah yes, indeed! For the 4th group that didn't succeed.
[28] I would say emotional because cognitive, there was less to do.
[29] I think it's still the same reason, because of the groups.

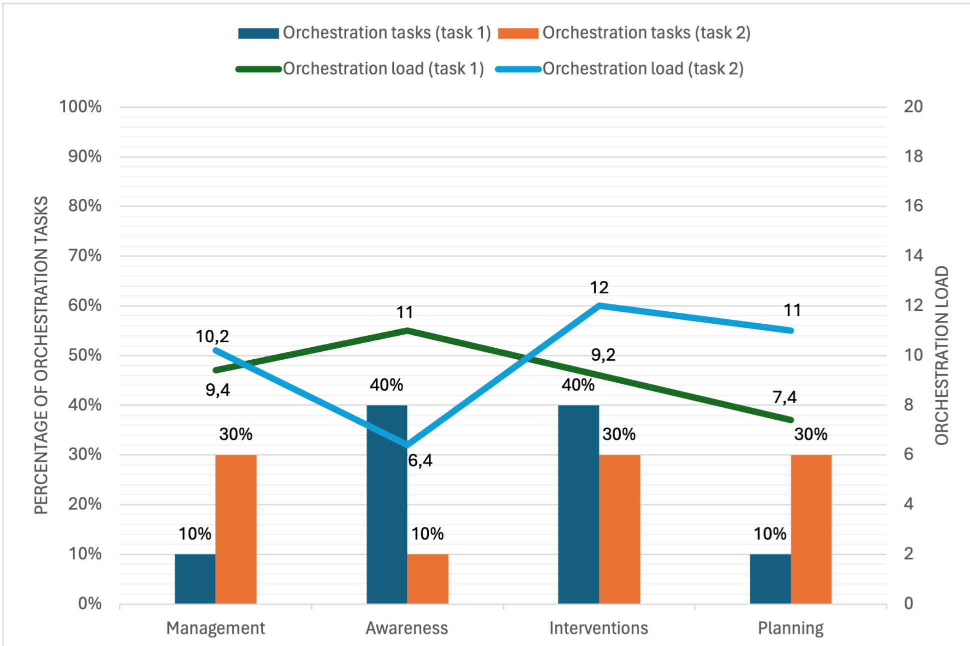


Figure 22: Pauline's orchestration tasks and associated load.

Martin's orchestration tasks primarily focus on management, which demonstrates relatively stable percentages with fluctuating loads. Initially, his management skill is observed at 65% with a moderate load of 10.6, which slightly increases to 70% accompanied by a heightened load of 13 during the scripted session.

In contrast, Martin's awareness remains low, beginning at 10% with a consistently high load of 12, only marginally increasing to 15% in a subsequent session, with the load also rising slightly to 12.6.

His interventions are consistently low at 5%, but the load increases significantly from 9.8 to 14, suggesting that despite the consistently low percentage, the demands in this area have increased.

Planning capabilities show variability, starting at a low 20% with a high load of 11.6, then decreasing to 10% with a reduced load of 9.6 in the scripted session. This shows that planning added a lot of orchestration load to Martin.

Pauline presents a contrasting profile, showcasing variability across different sessions. Initially, her management is low at 10% with a medium load of 9.4, which improves to 30% with a slightly higher load of 10.2. This shows that management brings additional orchestration load.

Her awareness starts at a high of 40% with a load of 11, but significantly drops to 10% with a reduced load of 6.4. This considerable fluctuation might indicate that the scripting in the session helped in reducing the load, thereby impacting her awareness.

Interventions initially are high at 40% with a medium load of 9.2, but reduce to 30% with an increased load of 12 in a later session. This indicates that while the scripted session demanded fewer intervention tasks, the load increased, suggesting a higher complexity in the tasks remaining.

Planning starts low at 10% with a load of 7.4, improving significantly to 30% with a load of 11. This shows that the scripted session required more extensive planning, which also brought about an increased load.

Both Martin and Pauline demonstrate different orchestration tasks. Martin shows mostly consistent orchestration tasks in management, awareness, planning and interventions. Pauline, on the other hand, shows variability in her orchestration tasks between the two sessions, with notable improvements in management and planning, which in turn required more load. Her awareness tasks and load were drastically reduced with the Pyramid script.

6 Discussion

This study sought to understand teachers' tasks when orchestrating collaborative robotics tasks and their associated orchestration load, particularly in the context of the use of Computer-Supported Collaborative Learning (CSCL) scripts. Our research aimed to bridge the gap in understanding the emotional load when orchestrating collaborative tasks with a collaborative script for junior and senior teachers.

Our qualitative exploratory approach revealed a distinct difference in orchestration load between junior and senior teachers using CSCL scripts. Junior teachers, when employing the Pyramid script, experienced a reduction in emotional load and a shift in cognitive load, facilitating a smoother orchestration. Specifically, it allowed junior teachers to shift their focus from monitoring and intervening to more strategic planning and management. This transformation highlights the potential of CSCL scripts to scaffold junior teachers' orchestration efforts by reducing the immediacy of monitoring needs.

In contrast, senior teachers reported increased emotional and cognitive loads with a script they did not personally develop. Martin's experience, which involved adapting group configurations due to limited robot availability, presented unexpected challenges. Such instances point to the nuanced impact of CSCL scripts on senior teachers, indicating a need for them to modify their established teaching routines. This could be explained by the fact that there is an interference between the internal and the external script (Kollar et al., 2007). Indeed, an experienced teacher has some established routines in terms of collaborative activity scripting, and this internal script could interfere with the external Pyramid script that we proposed.

Finally, we asked the teachers to define orchestration and orchestration load. They described orchestration as encompassing a wide range of activities, from pre-class preparation, such as resource planning, to in-class management and student monitoring. Orchestration load was characterized as the energy and effort required for these tasks, often intensified by a discrepancy between the observed classroom dynamics and the teacher's expectations: "*La charge, c'est le décalage entre ce qu'on voit et ce qu'on aimerait que ce soit.*" (Martin) [30]

[30] [Orchestration] load is the gap between what we see and what we would like it to be. (Martin)

6.1 RQ 1: What tasks do teachers perform when orchestrating collaborative robotics tasks?

Our first research question was about teachers' tasks when they orchestrated collaborative robotics activities. Our results revealed that CSCL scripts altered the orchestration tasks for teachers, particularly for junior teachers. Orchestration is a multifaceted activity encompassing pre-class preparation such as resource planning, and real-time classroom management, and student work monitoring. Paulines' orchestration tasks were completely transformed because she planned and managed more, so the need for awareness decreased. She also indicated that because of how the groups were scripted, she didn't have to check as often if the students understood or were able to solve the problem successfully. This suggests that the Pyramid CLFP alleviated the need for constant monitoring and intervention on her part.

Our hypothesis postulated that teachers' orchestration tasks would be the same as found in the literature by Prieto et al. (2011). And that they would be similar to what Shahmoradi et al. (2020) found when observing a class at EPFL. We found that managing was indeed the most important task done by teachers (between 10% to 70%). Secondly, interventions were also confirmed to be present in a great amount (between 5% to 40%). Thirdly, awareness was present (between 10% to 40%), followed by planning (between 10% to 30%), which was not considered in the study done by Shahmoradi et al. (2020).

Pauline indicated that she didn't plan much in the first session because everything was already planned by the researchers. She followed the plan exactly as it was presented, even having the preparation sheet in her hands at the beginning of the first session. She also didn't manage time, resources and space since she followed the planning exactly how it was meant to be. Whereas, in the second session, she had to prepare the formation of the groups and the disposition of the classroom. Pauline also indicated not planning any interventions and not having any awareness of each student in the second session. This seems logical since she had to follow the Pyramid script, which she indicated didn't require as much monitoring. In the first session, she didn't explain the rules of conduct or expected behaviour to the students, whereas she did it in the second session when they had to work with the Pyramid script. She indicated that she was not managing any relationships with or between the students. During the self-confrontation, she explained that she misunderstood the items "teacher to student relation" and "student to student relation" as she thought it was only problems amongst students or with the teacher: "*Parce qu'on a quand même toujours un contact avec les élèves, du coup, il y a quand même eu quelque chose. Mais j'ai presque vu ça dans un truc un peu problème, quoi. En mode, des problèmes entre élèves, style... y'a en un qui fait n'importe quoi.*" [31]

For junior teachers, the Pyramid script reduced the need for constant monitoring and intervention, allowing for a more focused approach to management, planning, and strategic interventions. In fact, when Pauline didn't plan much beforehand or manage her class, she had to intervene more and be highly aware to know what was happening in the classroom. This observation aligns with the work of Dillenbourg and Tchounikine (2007), who argue that CSCL scripts can scaffold learning processes. We believe that CSCL scripts could also

[31] Because we still always have contact with the students, so something (a relation) did happen. But I almost saw it as something of a problem. You know, problems between students, like... one of them does something crazy.

scaffold teacher orchestration by providing structured support, helping junior teachers distribute their cognitive load more effectively. This is supported by Kirschner et al. (2006), who emphasize the importance of guiding novice teachers, as they lack sufficient knowledge in long-term memory to avoid ineffective problem-solving. This support can be gradually reduced as expertise increases, allowing the knowledge stored in long-term memory to replace the need for external guidance. This concept is also known as the expertise reversal effect (Sweller et al., 2003). As such providing a CSCL script can help to scaffold and reduce orchestration load.

The integration of CSCL scripts into teaching practices introduces logistical and technical complexities, which is particularly evident in collaborative robotics tasks. Like Martin, senior teachers who use collaboration daily can encounter unexpected challenges because of adjusted group configurations due to robot availability constraints, which forces them to change their established routines. The expertise reversal effect (Sweller et al., 2003) could also explain why Martin didn't benefit as much from the scripted session because of his expertise. It is possible that the instructional method that was effective for Pauline, a junior teacher, becomes less effective as expertise increases. These scenarios highlight the nuanced impact of CSCL scripts on senior teachers because they need to reevaluate established pedagogical routines to accommodate the scripts' structured support.

Analysis of pie charts depicting Martin's and Pauline's self-reported orchestration tasks distribution across sessions offers further insights into the Pyramid script's effects on their orchestration strategies. If we compare both sessions, Martin manages more, has more awareness and plans less in the second session than the first, but the division of tasks remains very similar between the two sessions. For Pauline, the second session has much less monitoring, fewer interventions, and much more planning and management. It seems Pauline shifted her energy towards management and planning in her second session. If we compare both their orchestration tasks, we notice that their practices differ radically in the first session, with an equal focus on awareness and interventions for Pauline, while Martin focuses on management. Whereas in the second session, their practices are much more similar, with an equal focus on management, interventions and planning for Pauline and a focus on management for Martin. This redistribution of cognitive load, facilitated by the Pyramid script, underscores its potential to allow junior teachers like Pauline to invest more deeply in planning and management, reducing the burden of constant monitoring and interventions.

These findings collectively emphasize the transformative potential of CSCL scripts in reshaping the orchestration tasks of teachers, particularly for juniors. By reducing the immediacy of monitoring needs and enabling a focus on management, CSCL scripts like the Pyramid script can provide critical support for junior teachers navigating the complexities of collaborative robotics tasks. However, the experiences of Martin also highlight the challenges and adjustments required for senior teachers, underscoring the importance of considering individual teacher needs and contexts in the integration of CSCL scripts into educational practices.

6.2 RQ 2: What kind of load do teachers encounter when orchestrating collaborative robotics tasks?

The second research question focused on the type of orchestration load encountered by teachers. Our hypothesis postulated that there would be a cognitive and a physical load, like Prieto et al. (2015) showed in previous research, plus an emotional load. Firstly, our results show that teachers encountered cognitive load when teaching, with and without the presence of a script. Secondly, and contradicting previous research (Prieto et al., 2015), the physical load was barely noticed by both teachers. This shows that each load had a different intensity. Finally, emotional load plays an important role in orchestration load. This insight is a novel contribution to the existing literature and underscores the importance of considering emotional factors in future research on orchestration load.

For junior teachers, using the Pyramid script led to decreased emotional load and a shift in cognitive load towards more manageable tasks such as planning and management. The awareness dimension was reduced with the Pyramid script. This could be explained by the fact that less supervision was needed to make sure that each student understood the task, which would explain why Pauline didn't put monitoring each student in the second session. These findings align with the theoretical framework proposed by Sweller (1988) on cognitive load theory. His research is on optimizing cognitive load to enhance learning and performance. We can draw a parallel by suggesting that providing scripts to junior teachers may help reduce unnecessary extraneous cognitive load while enhancing essential intrinsic and germane cognitive loads.

The increase in orchestration load with the script for planning, class management and intervention tasks can be explained by the higher demand in preparation that was needed from the teachers and the additional group management that was needed to make sure that the students moved from working individually on the task to groups of two, and finally to groups of four. The increase in intervention load is difficult to explain since the number of intervention tasks didn't change or even reduced. It is possible that the Pyramid script required more scaffolding from the teachers since it was the only common task, but more research is needed to confirm this finding.

The detailed results revealed through self-reported data and visualized through the figures further illustrate this transformation. For example, the stress levels experienced by teachers, depicted in Figure 19, highlighted fluctuations that align with the introduction of the Pyramid script. Martin's and Pauline's experiences reflected contrasting trajectories in stress levels. Pauline experienced much less stress due to the group formation because she was certain the students would learn and understand at some point during the session, even if it wasn't immediately. The Pyramid script may offer several learning opportunities and, as such, give the students more chances to understand the task and underlying concepts. In fact, if we look at the Model of School Learning from Carroll (1963, p. 29), which stipulates that "students differ in the amount of learning time they need", the Pyramid script could give students more time to learn because they do the same task several times in different groups.

Martin, the senior teacher, reported an increase in emotional and cognitive loads, indicating that CSCL scripts could potentially disrupt established teaching practices. Martins' increase in planning in the first task shows perfectly how a senior teacher can get disturbed by an external script. Because he wasn't used to getting a plan from someone else and having to follow it, he got anxious and needed to change everything, which he was allowed to do in the first session but not in the scripted session. However, it's crucial to note that Martin uses a modified version of the Pyramid script in his daily practice, suggesting that the increased load may not all be script-related. We believe that these disruptions could also stem from deviations from usual group arrangements, potentially unsettling students. Moreover, Martin reported not being used to being observed in his own classroom and that it added an additional stress: "*Donc, là, d'être surveillé ou d'être analysé. Je pense que c'est un facteur de stress en tant que tel. Tant pendant l'activité qu'après.*" [32]. In contrast, Pauline, as a young teacher, is used to being observed because it is common to be observed during the first teaching years.

Despite initial teachers' perceptions of minimal physical load, reflections and further analysis suggested a potential underestimation of the physical demands involved in orchestration.

Pauline indicated upon reviewing the recording that she was running a lot, but that she hadn't noticed it while she was teaching. Martin explained that, because he had to take care of two groups in two separate rooms, he had to walk a lot to ensure everything was going well. This increased his physical load, but he hadn't considered it when completing the questionnaire. This could be linked to the Flow theory, which is a mental state reached by a person when they are completely immersed in an activity and are in a state of maximum concentration, full engagement and satisfaction in its accomplishment, without any effort (Csikszentmihalyi et al., 2005). Basically, flow is characterised by a person's total absorption in their occupation. The concept of flow, is usually related to enjoyable activities, however, it can also be present with stressful situations. If stress or anxiety can motivate and push a person to engage more deeply with the task at a level that matches their skills, it might facilitate entering a flow state (Jackson & Csikszentmihalyi, 1999). This happens when stress is a driver that focuses attention and efforts, much like athletes or performers who experience "good stress". In the same way, it is possible that Pauline didn't experience any physiological manifestation of stress in the second session because, in the flow of the action, she lost this self-consciousness (Heutte et al., 2021) to recognise her own physiological manifestations. These insights point to the complexity of orchestration and the difficulty teachers have in expressing the physical load they feel when teaching because it is a load they experience every day. This merits further exploration through objective measures such as measuring heartbeat or EDA (Electrodermal Activity).

6.3 RQ 3: To what extent do collaborative scripts affect teacher orchestration and teacher orchestration load?

The third question sought to understand how collaborative scripts affect teacher orchestration and its associated load. Our third hypothesis stipulated that the orchestration tasks would be different with the presence of a script and that the orchestration load would be

[32] So, being watched or analysed. I think that's a stress factor in itself. Both during the activity and afterwards.

reduced.

Our findings highlight the significant support CSCL scripts offer junior teachers in reducing orchestration load and underscore the challenges and adjustments senior teachers face. This distinction underscores the potential of CSCL scripts as a pivotal tool in supporting junior teachers, marking a novel contribution to the literature and suggesting a pathway for the targeted development and deployment of such scripts for junior teachers.

The deployment of the Pyramid script marked a significant transformation in the orchestration tasks, particularly for junior teachers like Pauline. The script effectively scaffolded her orchestration efforts, enabling a strategic shift towards planning, management, and targeted interventions. This shift is evidenced by the reduced need for constant monitoring and intervention, allowing for a more focused and efficient orchestration approach. The Pyramid script thus emerges as a potent tool in redistributing the cognitive load, aligning with the theoretical underpinnings of the Cognitive Load Theory by Sweller (1988), which emphasizes the importance of optimizing cognitive resources for effective task execution.

Moreover, the observed decrease in emotional load for junior teachers affirms the utility of CSCL scripts in reinforcing teaching efforts. Yet, senior teachers encountered distinct challenges, suggesting a need for CSCL scripts that offer flexibility and can be tailored to individual teaching styles and requirements. Although the emotional load was diminished for junior teachers, the cognitive load was increased for several dimensions, so we cannot say whether the orchestration load was reduced. Consequently, there is a pressing need for a comprehensive tool to measure orchestration load, encompassing cognitive, physical, and emotional dimensions.

6.4 Limitations of the study

Our study is drawn from qualitative data and the specific context of collaborative robotics tasks with primary students, which may limit generalizability. As the study was conducted within a specific institutional and cultural setting, this may influence the orchestration and participant dynamics in ways that are not universally applicable.

Additionally, data collection was confined to a small group of participants and conducted over a short duration, capturing only two moments in time, which may not sufficiently represent longer-term trends or broader dynamics. Such temporal limitations further restrict the applicability of these findings to other Computer-Supported Collaborative Learning (CSCL) scripts that may operate under different temporal or contextual variables.

Lastly, since we collected data solely on teachers' daily stress without assessing their stress levels before and after the sessions, we are unable to determine whether the teachers' stress levels were already elevated prior to the sessions.

6.5 Areas for future research

Further investigations should extend to different educational contexts and examine the long-term impacts of CSCL scripts on teacher development and student learning outcomes, providing a more comprehensive understanding of their pedagogical value.

Moreover, incorporating objective measurements could provide a clearer quantification of the orchestration load placed on participants by these scripts. Such data would offer valuable insights into the stressors and engagement factors associated with CSCL environments. Our initial plan was to use an Empatica E4 bracelet to measure the heartbeat and electrodermal activity (EDA), but as the results were unreliable, we chose not to.

Further research should continue to consider the experiences of both junior and senior teachers, as their varying levels of expertise may influence the implementation and outcomes of CSCL scripts.

Additionally, examining the well-being and performance of students within these settings can shed light on how different approaches to collaboration and learning impact student success. Indeed, as we haven't looked into students' performance after using the robots, it might be interesting to see if the Pyramid script impacted their learning.

Finally, we initially wanted to use *Pyramid App* created by Manathunga and Hernández-Leo (2018) to help the teachers orchestrate their classrooms. Still, the teachers were unconvinced after trying it and preferred to do it without. As *Pyramid App* is not made specifically for robotics, it cannot integrate codes or even images of programs. Therefore, it was complicated for the students to use. Teachers also found many connection issues and preferred not to add more stress to their teaching. This means that the tool could use some modifications to truly help the teachers with their orchestration and be used in classrooms.

7 Conclusion

This research aimed to explore teachers' tasks when orchestrating collaborative robotics tasks and the associated orchestration load when using Computer-Supported Collaborative Learning (CSCL) scripts. The findings suggest that CSCL scripts benefit junior teachers by providing guidance on facilitating student collaboration. The implementation of the Pyramid script streamlined the orchestration process by reducing emotional load and shifting cognitive load towards more strategic activities such as planning and management. This reduction in the immediacy of monitoring facilitated a more efficient orchestration. These observations indicate a potential for developing detailed and structured CSCL scripts that incorporate robotic activities to assist less experienced teachers, although further research is required to confirm these findings. This master thesis proposes a practical aspect for teachers with recommendations and a detailed script for a robot activity that teachers can follow, which can be found in the appendix 9.4.

Our findings also suggest that orchestration load includes emotional load, which provides a novel theoretical contribution to the existing literature. The junior teacher, Pauline, experienced much less stress with the Pyramid script. In contrast, Martin, the senior teacher, experienced increased emotional and cognitive loads, particularly when adapting to a script that was not self-developed. This increase can be attributed to the interference between their internalized teaching routines and the external demands of the CSCL scripts. Such findings suggest that while CSCL scripts offer substantial support for junior teachers, their application in the context of experienced teachers requires careful consideration to accommodate established teaching practices and personal adaptation strategies.

Furthermore, the study revealed a nuanced view of the physical load involved in orchestrating collaborative tasks, which the teachers themselves often underestimated. These findings underscore the complexity of teacher orchestration, which encompasses cognitive, physical and emotional load.

Due to the limited scope of this study, which included only two sessions with two teachers, more extensive research is necessary. Future studies should include more participants and sessions to provide a more comprehensive understanding of the orchestration and emotional loads teachers experience.

The concept of effective orchestration in teaching remains a challenging question. In the context of an orchestra, the quality of orchestration is readily apparent through the harmony and pacing of the music, guided effectively by the conductor. In contrast, defining "well-orchestrated" teaching is more complex. Does it require a balanced approach across various dimensions, such as management, awareness, interventions, and planning? Or is it more akin to the approach taken by Martin, the senior teacher, who prioritized management and planning over monitoring and intervening? At present, we do not have a definitive answer. However, it is clear that effective teacher orchestration is inherently linked to student engagement and outcomes. To assess whether teaching is well-orchestrated, one must consider the student's performance in activities (such as robotic activities) or their overall well-being in the classroom. Therefore, any observation or measurement of teacher orchestration must also account for student experiences and outcomes, as these elements are fundamentally interconnected. So, further investigations could examine the effects of CSCL scripts on student outcomes. This will provide a more comprehensive understanding of the pedagogical value of CSCL scripts and their role in enhancing both teacher and student experiences in collaborative learning environments.

As robotic technologies gain prevalence in educational settings, it is crucial to support teachers, especially junior teachers, in the technical and practical aspects of orchestrating these activities. Enhancing tools like the Pyramid App by making it easier for teachers to use and adding a way for students to add code could be beneficial for implementing this tool in robotic courses. In conclusion, this research has provided insights into the application of technology in education through the use of CSCL scripts. It is my hope that this thesis will contribute to the ongoing dialogue on how best to support educators in their crucial task of shaping future generations. By bridging the gap between technological innovation and pedagogical practice, we can ensure that educational technology fulfils its potential as a tool for effective and engaging learning.

8 Bibliography

References

Amarasinghe, I., Hernández Leo, D., Manatunga, K., Beardsley, M., Bosch Garcia, J., Carrió, M., Chacón Pérez, J., Jimenez Morales, M., Llanos Santos, D., Lope Pastor, S., et al. (2021). Collaborative learning designs using pyramidapp: Computer supported collaborative learning in classroom sessions. *Revista del Congrés Internacional de Docència Universitària i Innovació (CIDUI). 2021 Sep; 5.*

Amarasinghe, I., Vujovic, M., & Hernández Leo, D. (2020). Towards teacher orchestration load-aware teacher-facing dashboards. *Giannakos M, Spikol D, Molenaar I, Di Mitri D, Sharma K, Ochoa X, Hammad R, editors. Proceedings of CrossMMLA in practice: Collecting, annotating and analyzing multimodal data across spaces co-located with 10th International Learning and Analytics Conference (LAK 2020); 2020 Mar 24. Aachen: CEUR; 2020. p. 7-10.*

Baddeley, A., Logie, R., Bressi, S., Sala, S. D., & Spinnler, H. (1986). Dementia and working memory. *The Quarterly Journal of Experimental Psychology Section A*, *38*(4), 603–618.

Beilock, S. L., Kulp, C. A., Holt, L. E., & Carr, T. H. (2004). More on the fragility of performance: Choking under pressure in mathematical problem solving. *Journal of Experimental Psychology: General*, *133*(4), 584.

Bellemain, F., & Trouche, L. (2016). Comprendre le travail des professeurs avec les ressources de leur enseignement, un questionnement didactique et informatique. *I Simpósio Latino-Americano de Didática da Matemática*.

Bissonnette, S., Richard, M., Gauthier, C., & Bouchard, C. (2010). Quelles sont les stratégies d'enseignement efficaces favorisant les apprentissages fondamentaux auprès des élèves en difficulté de niveau élémentaire? résultats d'une méga-analyse. *Revue de recherche appliquée sur l'apprentissage*, *3*(1).

Borge, M., & White, B. (2016). Toward the development of socio-metacognitive expertise: An approach to developing collaborative competence. *Cognition and Instruction*, *34*(4), 323–360.

Bright, K., & Calabro, K. (1999). Child care workers and workplace hazards in the united states: Overview of research and implications for occupational health professionals. *Occupational medicine*, *49*(7), 427–437.

Brunken, R., Plass, J. L., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational psychologist*, *38*(1), 53–61.

Caci, H., Deschaux, O., & Baylé, F. J. (2007). Psychometric properties of the french versions of the bis/bas scales and the spsrq. *Personality and individual differences*, *42*(6), 987–998.

Cain, B. (2007). A review of the mental workload literature. *DTIC Document*.

Carroll, J. B. (1963). A model of school learning. *Teachers college record*, *64*(8), 1–9.

Chevalier, M., Riedo, F., & Mondada, F. (2016). Pedagogical uses of thymio ii: How do teachers perceive educational robots in formal education? *IEEE Robotics & Automation Magazine*, *23*(2), 16–23.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and brain sciences*, *24*(1), 87–114.

Crook, C. (1995). On resourcing a concern for collaboration within peer interactions. *Cognition and instruction*, *13*(4), 541–547.
Csikszentmihalyi, M., Abuhamdeh, S., & Nakamura, J. (2005). Flow. *Handbook of competence and motivation*, 598–608.
Cuendet, S., Bonnard, Q., Do-Lenh, S., & Dillenbourg, P. (2013). Designing augmented reality for the classroom. *Computers Education*, *68*, 557–569. https://doi.org/10.1016/j.compedu.2013.02.015
Dillenbourg, P. (2002). Over-scripting cscl: The risks of blending collaborative learning with instructional design.
Dillenbourg, P. (2011). Trends in orchestration. second research & technology scouting report.
Dillenbourg, P. (2013). Design for classroom orchestration. *Computers & education*, *69*, 485–492.
Dillenbourg, P. (2015). *Orchestration graphs*. IATED.
Dillenbourg, P., & Betrancourt, M. (2006). Collaboration load. *Handling complexity in learning environments: Theory and research*, 141–165.
Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). *The evolution of research on computer-supported collaborative learning: From design to orchestration*. Springer.
Dillenbourg, P., & Jermann, P. (2010). Technology for classroom orchestration. *New science of learning: Cognition, computers and collaboration in education*, 525–552.
Dillenbourg, P., Prieto, L. P., & Olsen, J. K. (2018). Classroom orchestration. *International handbook of the learning sciences*, 180–190.
Dillenbourg, P., & Tchounikine, P. (2007). Flexibility in macro-scripts for computer-supported collaborative learning. *Journal of computer assisted learning*, *23*(1), 1–13.
Dimitriadis, Y., Asensio-Pérez, J. I., Hernández-Leo, D., Roschelle, J., Brecha, J., Tatar, D., Chaudhury, R., DiGiano, C., et al. (2007). From socially-mediated to technology-mediated coordination: A study of design tensions using group scribbles.
Do-Lenh, S., Jermann, P., Legge, A., Zufferey, G., & Dillenbourg, P. (2012). Tinkerlamp 2.0: Designing and evaluating orchestration technologies for the classroom. *21st Century Learning for 21st Century Skills: 7th European Conference of Technology Enhanced Learning, EC-TEL 2012, Saarbrücken, Germany, September 18-21, 2012. Proceedings 7*, 65–78.
Feldon, D. F. (2007). Cognitive load and classroom teaching: The double-edged sword of automaticity. *Educational psychologist*, *42*(3), 123–137.
Fiore, L., Rodriguez, H., & Shriver, C. (2017). Collaboration to accelerate proteogenomics cancer care: The department of veterans affairs, department of defense, and the national cancer institute's applied proteogenomics organizational learning and outcomes (apollo) network. *Clinical Pharmacology & Therapeutics*, *101*(5), 619–621.
Fischer, F., & Dillenbourg, P. (2006). Challenges of orchestrating computer-supported collaborative learning. *87th annual meeting of the American Educational Research Association (AERA)*.
Fraser, K. L., Ayres, P., & Sweller, J. (2015). Cognitive load theory for the design of medical simulations. *Simulation in Healthcare*, *10*(5), 295–307.
Frenzel, A. C., Becker-Kurz, B., Pekrun, R., Goetz, T., & Lüdtke, O. (2018). Emotion transmission in the classroom revisited: A reciprocal effects model of teacher and student enjoyment. *Journal of Educational Psychology*, *110*(5), 628.
Frenzel, A. C., Daniels, L., & Burić, I. (2021). Teacher emotions in the classroom and their implications for students. *Educational Psychologist*, *56*(4), 250–264.

Frenzel, A. C., Pekrun, R., Goetz, T., Daniels, L. M., Durksen, T. L., Becker-Kurz, B., & Klassen, R. M. (2016). Measuring teachers' enjoyment, anger, and anxiety: The teacher emotions scales (tes). *Contemporary Educational Psychology*, *46*, 148–163.

Gaillard, A. W. (1993). Comparing the concepts of mental load and stress. *Ergonomics*, *36*(9), 991–1005.

Gaudiello, I., & Zibetti, E. (2013). La robotique éducationnelle: État des lieux et perspectives. *Psychologie française*, *58*(1), 17–40.

Gaudreau, N. (2019). *Gérer efficacement sa classe: Les cinq ingrédients essentiels*. PUQ.

Gonulal, T., & Loewen, S. (2018). Scaffolding technique. *The TESOL encyclopedia of English language teaching*, 1–5.

Gratz, R. R., & Claffey, A. (1996). Adult health in child care: Health status, behaviors, and concerns of teachers, directors, and family child care providers. *Early Childhood Research Quarterly*, *11*(2), 243–267.

Gratz, R. R., Claffey, A., King, P., & Scheuer, G. (2002). The physical demands and ergonomics of working with young children. *Early Child Development and Care*, *172*(6), 531–537.

Hämäläinen, R., Kiili, C., & Smith, B. E. (2017). Orchestrating 21st century learning in higher education: A perspective on student voice. *British Journal of Educational Technology*, *48*(5), 1106–1118.

Hart, S. G., & Staveland, L. E. (1988). Development of nasa-tlx (task load index): Results of empirical and theoretical research. In *Advances in psychology* (pp. 139–183). Elsevier.

Hellemans, C., Zawieja, P. P., & Guarnieri, F. (2014). Charge émotionnelle. *Dictionnaire des risques psychosociaux*, 90–92.

Henri, F., & Lundgren-Cayrol, K. (2001). Les environnements de collaboration a distance. *Québec: Presses de l'université du Québec*.

Hernández-Leo, D., Villasclaras-Fernández, E. D., Asensio-Pérez, J. I., Dimitriadis, Y., Jorrın-Abellán, I. M., Ruiz-Requies, I., & Rubia-Avi, B. (2006). Collage: A collaborative learning design editor based on patterns. *Journal of Educational Technology & Society*, *9*(1), 58–71.

Heutte, J., Fenouillet, F., Martin-Krumm, C., Gute, G., Raes, A., Gute, D., Bachelet, R., & Csikszentmihalyi, M. (2021). Optimal experience in adult learning: Conception and validation of the flow in education scale (eduflow-2). *Frontiers in Psychology*, *12*, 828027.

Hostetler, L. (1984). The nanny trap: Child care work today. *Young Children*, 76–79.

Hsu, S.-H., Chou, C.-Y., Chen, F.-C., Wang, Y.-K., & Chan, T.-W. (2007). An investigation of the differences between robot and virtual learning companions' influences on students' engagement. *2007 First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL'07)*, 41–48.

Inventaire des préoccupations des enseignants. (n.d.). Retrieved April 27, 2024, from https://www.scribd.com/document/677264720/inventaire-du-stress-des-enseignants

Isen, A. M., & Reeve, J. (2005). The influence of positive affect on intrinsic and extrinsic motivation: Facilitating enjoyment of play, responsible work behavior, and self-control. *Motivation and emotion*, *29*, 295–323.

Jackson, S. A., & Csikszentmihalyi, M. (1999). *Flow in sports*. Human Kinetics.

Jones, K. A., Jones, J. L., & Vermette, P. J. (2013). Exploring the complexity of classroom management: 8 components of managing a highly productive, safe, and respectful urban environment. *American Secondary Education*, 21–33.

Jormanainen, I. (2013). *Supporting teachers in unpredictable robotics learning environments* (Doctoral dissertation). Itä-Suomen yliopisto.
Kahn, S. (2017). *Pédagogie différenciée: Guide pédagogique*. De Boeck (Pédagogie et Formation).
Kennewell, S., Tanner, H., Jones, S., & Beauchamp, G. (2008). Analysing the use of interactive technology to implement interactive teaching. *Journal of computer assisted learning*, *24*(1), 61–73.
Kerangueven, L., & Claudon, L. (2023). Une méthode pour l'analyse de la charge physique de travail. *Archives des Maladies Professionnelles et de l'Environnement*, *84*(2), 101749.
Khodr, H., Ramage, U., Kim, K., Guneysu Ozgur, A., Bruno, B., & Dillenbourg, P. (2020). Being part of the swarm: Experiencing human-swarm interaction with vr and tangible robots. *Proceedings of the 2020 ACM Symposium on Spatial User Interaction*, 1–2.
Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational psychologist*, *41*(2), 75–86.
Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P., & Fischer, F. (2007). Specifying computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning*, *2*, 211–224.
Kollar, I., & Fischer, F. (2013). Orchestration is nothing without conducting–but arranging ties the two together!: A response to dillenbourg (2011). *Computers & Education*, *69*, 507–509.
Kollar, I., Fischer, F., & Slotta, J. D. (2007). Internal and external scripts in computer-supported collaborative inquiry learning. *Learning and Instruction*, *17*(6), 708–721.
LeDoux, J. E., & Brown, R. (2017). A higher-order theory of emotional consciousness. *Proceedings of the National Academy of Sciences*, *114*(10), E2016–E2025.
Longo, L. (2011). Human-computer interaction and human mental workload: Assessing cognitive engagement in the world wide web. *Human-Computer Interaction–INTERACT 2011: 13th IFIP TC 13 International Conference, Lisbon, Portugal, September 5-9, 2011, Proceedings, Part IV 13*, 402–405.
Lysaght, R. J., Hill, S. G., Dick, A., Plamondon, B. D., Linton, P. M., Wierwille, W. W., Zaklad, A. L., Bittner, A., & Wherry, R. J. (1989). *Operator workload: Comprehensive review and evaluation of operator workload methodologies*. NTIS (Reprod.)
Manathunga, K., & Hernández-Leo, D. (2018). Authoring and enactment of mobile pyramid-based collaborative learning activities. *British Journal of Educational Technology*, *49*(2), 262–275.
Manathunga, K., Hernández-Leo, D., & Sharples, M. (2017). A social learning space grid for moocs: Exploring a futurelearn case. *Digital Education: Out to the World and Back to the Campus: 5th European MOOCs Stakeholders Summit, EMOOCs 2017, Madrid, Spain, May 22-26, 2017, Proceedings 5*, 243–253.
Matarić, M. J., Eriksson, J., Feil-Seifer, D. J., & Winstein, C. J. (2007). Socially assistive robotics for post-stroke rehabilitation. *Journal of neuroengineering and rehabilitation*, *4*, 1–9.
Miller, S. (2001). Workload measures. *National Advanced Driving Simulator. Iowa City, United States*.

Nouri, J. (2014). *Orchestrating scaffolded outdoor mobile learning activities* (Doctoral dissertation). Department of Computer and Systems Sciences, Stockholm University.

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational psychologist*, *38*(1), 1–4.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature reviews neuroscience*, *9*(2), 148–158.

Phelps, E. A. (2004). Human emotion and memory: Interactions of the amygdala and hippocampal complex. *Current opinion in neurobiology*, *14*(2), 198–202.

Pi, Z., Yang, H. H., Chen, W., Hu, X., & Li, X. (2022). The role of teachers' emotions in students' outcomes: From the perspective of interpersonal emotions. *Frontiers in Psychology*, *13*, 1075110.

Pierrot, L., & Cerisier, J.-F. (2022). Le rôle des techniques d'intelligence artificielles dans l'orchestration pédagogique et didactique comme nouvelle dimension de l'hybridation des dispositifs de formation. *Ticemed13: Hybridation des formations: de la continuité à l'innovation pédagogique?*

Piquet, A. (2009). Guide pratique du travail collaboratif: Théories, méthodes et outils au service de la collaboration. *Document destiné au Groupe Communication du réseau Isolement Social*, *17*(2), 7–9.

Plass, J. L., & Kalyuga, S. (2019). Four ways of considering emotion in cognitive load theory. *Educational Psychology Review*, *31*, 339–359.

Prieto, L. P., Holenko Dlab, M., Gutiérrez, I., Abdulwahed, M., & Balid, W. (2011). Orchestrating technology enhanced learning: A literature review and a conceptual framework. *International Journal of Technology Enhanced Learning*, *3*(6), 583–598.

Prieto, L. P., Sharma, K., & Dillenbourg, P. (2015). Studying teacher orchestration load in technology-enhanced classrooms: A mixed-method approach and case study. *Design for Teaching and Learning in a Networked World: 10th European Conference on Technology Enhanced Learning, EC-TEL 2015, Toledo, Spain, September 15-18, 2015, Proceedings 10*, 268–281.

Prieto, L. P., Sharma, K., Kidzinski, & Dillenbourg, P. (2017). Orchestration load indicators and patterns: In-the-wild studies using mobile eye-tracking. *IEEE Transactions on Learning Technologies*, *11*(2), 216–229.

Prieto, L. P., Wen, Y., Caballero, D., Sharma, K., & Dillenbourg, P. (2014). Studying teacher cognitive load in multi-tabletop classrooms using mobile eye-tracking. *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces*, 339–344.

Radkowitsch, A., Vogel, F., & Fischer, F. (2020). Good for learning, bad for motivation? a meta-analysis on the effects of computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning*, *15*, 5–47.

Roschelle, J., Dimitriadis, Y., & Hoppe, U. (2013). Classroom orchestration: Synthesis. *Computers & Education*, *69*, 523–526.

Rothstein-Fisch, C., & Trumbull, E. (2008). *Managing diverse classrooms: How to build on students' cultural strengths*. Ascd.

Rummel, N., & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem solving in computer-mediated settings. *The journal of the Learning Sciences*, *14*(2), 201–241.

Schenkenberg van Mierop, E., & Schmidt, A.-L. (2022). *Robotique éducative et développement de la décentration pour le repérage dans le plan et l'espace en mathématiques* (Mémoire de Bachelor). Haute École Pédagogique de Lausanne. http://patrinum.ch/record/328640

Schenkenberg van Mierop, E., Schmidt, A.-L., & Chevalier, M. (2023). Effects of the use of robots on algorithmization, decentration and locating in the plane skills. *16th International Conference on Informatics in Schools, ISSEP 2023, Local Proceedings.* https://doi.org/https://doi.org/10.5281/zenodo.8431728

Schneider, D. (2004). Learning together through collaborative portal sites. *A Learning Zone of One's Own: Sharing Representations and Flow in Collaborative Learning Environments*, 193–220.

Shahmoradi, S., Kothiyal, A., Bruno, B., Dillenbourg, P., & Olsen, J. K. (2020). What teachers need for orchestrating robotic classrooms. *Addressing Global Challenges and Quality Education*, 14. 87–101. https://doi.org/https://doi.org/10.1007/978-3-030-57717-9_7

Shahmoradi, S., Olsen, J. K., Haklev, S., Johal, W., Norman, U., Nasir, J., & Dillenbourg, P. (2019). Orchestration of robotic activities in classrooms: Challenges and opportunities. *European Conference on Technology Enhanced Learning*, 640–644.

Sharples, M. (2013). Shared orchestration within and beyond the classroom. *Computers & Education*, *69*, 504–506.

Studer, R., & Quarroz, S. (2017). Enquête sur la santé des enseignants romands: Rapport: Regina studer, stéphane quarroz.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive science*, *12*(2), 257–285.

Sweller, J. (1999). Instructional design in technical areas. camberwell. *Victoria: ACER Press.*

Sweller, J. (2010). Cognitive load theory: Recent theoretical advances.

Sweller, J. (2011). Cognitive load theory. In *Psychology of learning and motivation* (pp. 37–76). Elsevier.

Sweller, J., Ayres, P. L., Kalyuga, S., & Chandler, P. (2003). The expertise reversal effect.

Trouche, L. (2003). Construction et conduite des instruments dans les apprentissages mathématiques: Nécessité des orchestrations.

Van de Weerdt, C., Morel, O., & Caël, C. (2017). Prévention des situations à risque de forte charge émotionnelle: Exemple dans le secteur de l'aide à domicile. *Psychologie du travail et des organisations*, *23*(4), 326–343.

VandenBos, G. R. (2007). *Apa dictionary of psychology.* American Psychological Association.

Verwey, W. B. (1990). Adaptable driver-car interfacing and mental workload: A review of the literature.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The panas scales. *Journal of personality and social psychology*, *54*(6), 1063.

Watts, M. (2003). The orchestration of learning and teaching methods in science education. *Canadian Journal of Math, Science & Technology Education*, *3*(4), 451–464.

Wortman, A. M. (2001). Preventing work-related musculoskeletal injuries. *Child Care Information Exchange*, 50–53.

9 Appendix

9.1 Demographic questionnaire

Nom et Prénom :

1. Quel est votre genre ?
   - ☐ Féminin
   - ☐ Masculin
   - ☐ Autre

2. Quel âge avez-vous ? __________ ans

3. Combien d'années d'expérience professionnelle avez-vous ? __________ ans

4. À quel degré enseignez-vous ?
   - ☐ 5-6P
   - ☐ 7-8P

5. Combien d'élèves avez-vous dans votre classe ? __________ élèves

6. Cette année, j'enseigne les cours de (plusieurs réponses possibles) :
   - ☐ Français
   - ☐ Mathématiques
   - ☐ Sciences de la nature
   - ☐ Allemand
   - ☐ Anglais
   - ☐ Histoire
   - ☐ Géographie
   - ☐ Éthique et cultures religieuses
   - ☐ Activités créatrices et manuelles
   - ☐ Arts visuels
   - ☐ Musique
   - ☐ Éducation physique
   - ☐ Éducation numérique

1. *Cochez la case correspondante*

	Tous les jours	Plusieurs fois par semaine	Plusieurs fois par mois	Plusieurs fois par années	Jamais
À quelle fréquence utilisez-vous la technologie en classe ?					
À quelle fréquence utilisez-vous des robots en classe ?					

2. Quels outils utilisez-vous ?
   - ☐ Un projecteur
   - ☐ Un tableau interactif
   - ☐ Des ordinateurs
   - ☐ Des iPads
   - ☐ Des robots Blue-Bot
   - ☐ Des robots Thymio
   - ☐ Autres, préciser : ______________________________________

3. Avez-vous déjà utilisé des robots en classe dans le passé ? Si oui, veuillez expliquer brièvement votre expérience.

____

____

4. Avez-vous suivi une formation spécifique à l'utilisation de la robotique en classe ?

   - ☐ Oui, préciser : ______________________________________
   - ☐ Non

5. Quels sont les principaux défis auxquels vous êtes confronté lorsque vous utilisez l'informatique en classe ? (plusieurs réponses possibles)

   - ☐ La gestion du temps
   - ☐ La gestion de la classe
   - ☐ La gestion de la technologie
   - ☐ Suivre la progression des élèves
   - ☐ La gestion de l'indiscipline
   - ☐ Autres, préciser : ______________________________________

1. *Cochez la case correspondante*

	Tous les jours	Plusieurs fois par semaine	Plusieurs fois par mois	Plusieurs fois par années	Jamais
À quelle fréquence faites-vous travailler vos élèves en groupe ?					

2. Quelle importance accordez-vous à la collaboration dans vos cours ?

Pas importante	Peu importante	Moyennement importante	Importante	Très importante
○	○	○	○	○

3. Comment gérez-vous les groupes de travail en classe ? (plusieurs réponses possibles)

- ☐ Je choisis les membres des groupes de manière aléatoire
- ☐ Je forme les groupes en fonction de leurs affinités
- ☐ Je laisse les élèves choisir leur groupe
- ☐ Je fais en sorte que les groupes soient mixtes en termes de niveau
- ☐ Autres, préciser : ____

4. Quels sont les principaux défis auxquels vous êtes confronté lors de la mise en place de la collaboration entre élèves ? (plusieurs réponses possibles)

- ☐ La résistance des élèves à collaborer avec certains pairs
- ☐ La gestion du temps
- ☐ La gestion des conflits
- ☐ L'équité dans la répartition des tâches
- ☐ Autres, préciser : ____

9.2 Stress and emotions questionnaire given before and after the sessions

STRESS ET ÉMOTIONS DES ENSEIGNANTS

Nom et Prénom :

Veuillez indiquer **le stress que vous ressentez au quotidien** lorsque vous enseignez.

1. De manière générale, lorsque j'effectue des activités collaboratives avec mes élèves je ressens du stress :

   0 1 2 3 4 5 6 7 8 9 10

---

2. Pour chacun des adjectifs, indiquez ce que vous ressentez lorsque vous effectuez des activités collaboratives avec vos élèves.

		Très peu ou pas du tout	Un peu	Moyennement	Beaucoup	Énormément
1	Stressé	1	2	3	4	5
2	Agressif	1	2	3	4	5
3	Alerte	1	2	3	4	5
4	Honteux	1	2	3	4	5
5	Inspiré	1	2	3	4	5
6	Nerveux	1	2	3	4	5
7	Déterminé	1	2	3	4	5
8	Attentif	1	2	3	4	5
9	Actif	1	2	3	4	5
10	Inquiet	1	2	3	4	5

MALTT

MANIFESTATIONS DU STRESS

Veuillez identifier les **manifestations corporelles et physiologiques du stress** que vous ressentez lorsque vous effectuez des activités collaboratives avec vos élèves sur une échelle d’intensité de 1 (pas du tout) à 5 (beaucoup).

Je réagis au stress...

1. … en ressentant un état d'épuisement physique.	1	2	3	4	5
2. … avec une tension musculaire (cou, épaules, dos)	1	2	3	4	5
3. … avec une posture de corps rigide	1	2	3	4	5
4. … avec une sensation d'accélération du cœur.	1	2	3	4	5
5. … avec une respiration rapide.	1	2	3	4	5
6. … avec une augmentation de la transpiration	1	2	3	4	5
7. … avec une augmentation de la vitesse de parole	1	2	3	4	5
8. … avec des maux de tête	1	2	3	4	5
9. … avec des crampes d'estomac.	1	2	3	4	5
10. … avec des nausées	1	2	3	4	5
11. … avec une bouche sèche	1	2	3	4	5
12. … avec une boule dans la gorge	1	2	3	4	5
13. … avec des tremblements (mains ou autres parties du corps)	1	2	3	4	5
14. … avec une augmentation de mon agitation	1	2	3	4	5
15. … en me rongeant les ongles	1	2	3	4	5
16. … en jouant avec mes cheveux	1	2	3	4	5
17. … en tapotant des pieds	1	2	3	4	5
18. … en serrant les dents	1	2	3	4	5
19. … en touchant régulièrement mon visage	1	2	3	4	5
20. … en croisant les bras	1	2	3	4	5

STRESS ET ÉMOTIONS DES ENSEIGNANTS

Nom et Prénom :

Veuillez indiquer **le stress que vous avez ressenti lors de l'activité effectuée**.

1. Lors de l'activité collaborative en robotique, j'ai ressenti du stress :

0 1 2 3 4 5 6 7 8 9 10

---

2. Pour chacun des adjectifs, indiquez ce que vous avez ressenti lors de l'activité.

		Très peu ou pas du tout	Un peu	Moyennement	Beaucoup	Énormément
1	Stressé	1	2	3	4	5
2	Agressif	1	2	3	4	5
3	Alerte	1	2	3	4	5
4	Honteux	1	2	3	4	5
5	Inspiré	1	2	3	4	5
6	Nerveux	1	2	3	4	5
7	Déterminé	1	2	3	4	5
8	Attentif	1	2	3	4	5
9	Actif	1	2	3	4	5
10	Inquiet	1	2	3	4	5

MALTT

MANIFESTATIONS DU STRESS

Veuillez identifier les **manifestations corporelles et physiologiques du stress** que vous avez ressenti lorsque vous avez effectué l'activité collaborative en robotique sur une échelle d'intensité de 1 (pas du tout) à 5 (beaucoup).

Je réagis au stress...

1. … en ressentant un état d'épuisement physique.	1	2	3	4	5
2. … avec une tension musculaire (cou, épaules, dos)	1	2	3	4	5
3. … avec une posture de corps rigide	1	2	3	4	5
4. … avec une sensation d'accélération du cœur.	1	2	3	4	5
5. … avec une respiration rapide.	1	2	3	4	5
6. … avec une augmentation de la transpiration	1	2	3	4	5
7. … avec une augmentation de la vitesse de parole	1	2	3	4	5
8. … avec des maux de tête	1	2	3	4	5
9. … avec des crampes d'estomac.	1	2	3	4	5
10. … avec des nausées	1	2	3	4	5
11. … avec une bouche sèche	1	2	3	4	5
12. … avec une boule dans la gorge	1	2	3	4	5
13. … avec des tremblements (mains ou autres parties du corps)	1	2	3	4	5
14. … avec une augmentation de mon agitation	1	2	3	4	5
15. … en me rongeant les ongles	1	2	3	4	5
16. … en jouant avec mes cheveux	1	2	3	4	5
17. … en tapotant des pieds	1	2	3	4	5
18. … en serrant les dents	1	2	3	4	5
19. … en touchant régulièrement mon visage	1	2	3	4	5
20. … en croisant les bras	1	2	3	4	5

9.3 Orchestration questionnaire

Nom et Prénom :

Pour chaque dimension de l'orchestration, **indiquez le pourcentage** qui vous semble le plus représentatif de ce que vous avez réalisé lors de la séance passée puis **cochez**, pour chaque dimension, ce qui a été réalisé.

Planification : ……………… %
o planification de l'activité o planification du matériel o planification de la salle de classe o planification de mes interventions au cours de l'activité

Gestion : ……………… %

o Gestion des ressources
  o gestion du temps
  o gestion du matériel
  o gestion de l'espace
  o gestion des technologies

o attentes claires
  o règles de conduite
  o consignes
  o routines
  o comportement attendu
  o rétroaction positive

o relations sociales
  o élève - enseignant
  o élève - élève

o engagement dans la tâche
  o perception de la tâche
  o participation active
  o différenciation
  o progression dans la tâche
  o évaluations

- indiscipline
    - préventive
    - réactive

Awareness (prise d'information dans le flux de l'action) et régulation : ………… %
o prise d'information sur l'état de la classe o prise d'information sur chaque élève o suivi et régulation

Interventions et adaptations : ……………… %
o évènements inattendus o débriefing o étayage o modification de la planification

QUESTION :

Pourriez-vous indiquez très brièvement quels sont les moments critiques qui sont apparus lors de l'activité ?

____

____

____

____

Nom et Prénom :

NASA Task Load Index

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

PLANIFICATION

Charge mentale : À quel degré des activités telles que penser, percevoir, décider, calculer, se souvenir, observer, chercher, etc. ont eu lieu lors de la planification ?

Très bas Très élevé

Charge physique : À quel degré des activités telles que pousser, tirer, tourner, contrôler, activer, etc. ont eu lieu lors de la planification ?

Très bas Très élevé

Pression temporelle : À quel degré avez-vous eu l'impression d'être pressé pour réaliser cette planification ?

Très bas Très élevé

Performance : À quel degré êtes-vous satisfait de votre planification ?

Très bas Très élevé

Effort : L'effort à fournir pour planifier la séance était-il faible ou élevé ?

Très bas Très élevé

GESTION

Charge mentale : À quel degré des activités telles que penser, percevoir, décider, calculer, se souvenir, observer, chercher, etc. ont eu lieu lors de la gestion ?

Très bas Très élevé

Charge physique : À quel degré des activités telles que pousser, tirer, tourner, contrôler, activer, etc. ont eu lieu lors de la gestion ?

Très bas Très élevé

Pression temporelle : À quel degré avez-vous eu l'impression d'être pressé pour gérer ?

Très bas Très élevé

Performance : À quel degré êtes-vous satisfait de votre gestion ?

Très bas Très élevé

Effort : L'effort à fournir pour gérer était-il faible ou élevé ?

Très bas Très élevé

AWARENESS (prise d’information) et RÉGULATION

Charge mentale : À quel degré des activités telles que penser, percevoir, décider, calculer, se souvenir, observer, chercher, etc. ont eu lieu lors de la prise d’information et de la régulation ?

Très bas Très élevé

Charge physique : À quel degré des activités telles que pousser, tirer, tourner, contrôler, activer, etc. ont eu lieu lors de la prise d’information et de la régulation ?

Très bas Très élevé

Pression temporelle : À quel degré avez-vous eu l’impression d’être pressé par le temps lors de la prise d'information et de la régulation ?

Très bas Très élevé

Performance : À quel degré êtes-vous satisfait de la prise d’information et de la régulation ?

Très bas Très élevé

Effort : L’effort à fournir pour prendre l’information et réguler était-il faible ou élevé ?

Très bas Très élevé

INTERVENTIONS ET ADAPTATIONS

Charge mentale : À quel degré des activités telles que penser, percevoir décider, calculer, se souvenir, observer, chercher, etc. ont eu lieu lors des interventions et adaptations ?

Très bas Très élevé

Charge physique : À quel degré des activités telles que pousser, tirer, tourner, contrôler, activer, etc. ont eu lieu lors des interventions et adaptations ?

Très bas Très élevé

Pression temporelle : À quel degré avez-vous eu l'impression d'être pressé pour intervenir et adapter ?

Très bas Très élevé

Performance : À quel degré êtes-vous satisfait de vos interventions et adaptations ?

Très bas Très élevé

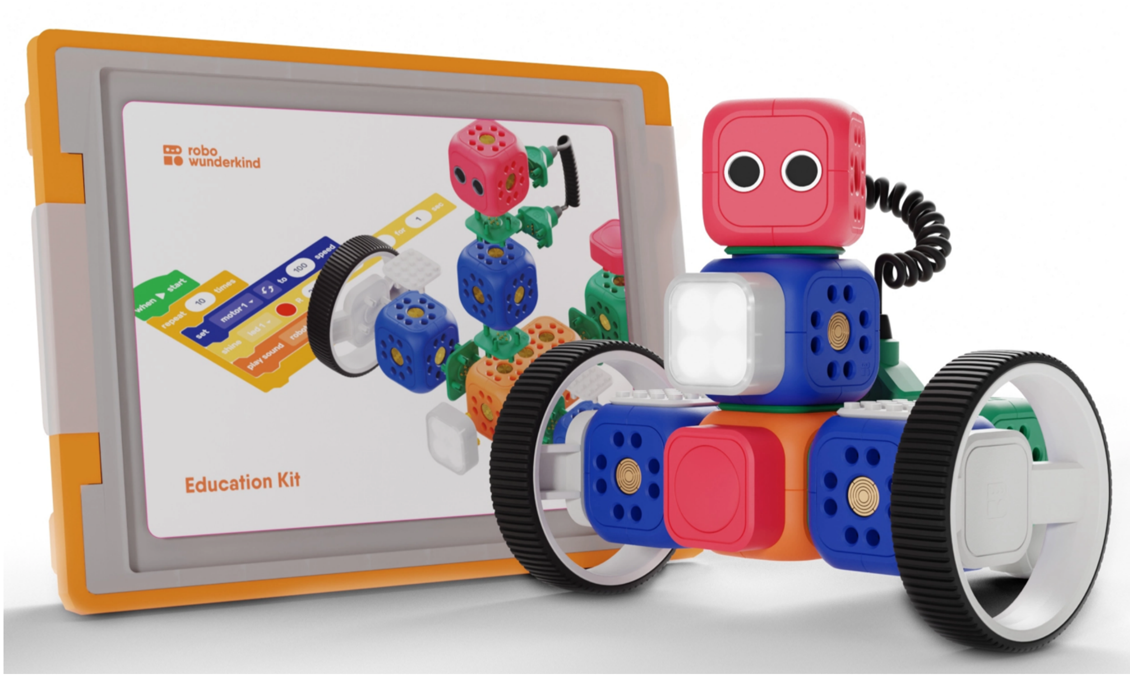
Effort : L'effort à fournir pour intervenir et adapter était-il faible ou élevé ?

Très bas Très élevé

9.4 Pyramid script for robotic activities

Pyramid CLFP with a robotic activity

Activity time: 2 hours
Robot : Robo Wunderkind https://www.robowunderkind.com/



Documentation :

- PER : https://portail.ciip.ch/per/disciplines/23
- Teacher's guide:
  https://uploads-ssl.webflow.com/5ed0d9d3a20c8f1906ca6434/5f9858042c976dce669ae76b_1.2%20Teacher_s%20Guide.pdf
- Various resources in German and English:
  https://www.robowunderkind.com/educational-materials

Operation Biodiversity Rescue

<table>
<tr><td colspan="2">PER EN 22 - Learn the basic concepts of computer science by creating, executing, comparing and correcting programs.</td></tr>
<tr><td>Objective of the session</td><td>Material</td></tr>
<tr><td>- Identify the different parts of the robot
- Explain the characteristics of the robot
- Create a programme with sequences to solve a problem
- Compare your programme to solve a problem</td><td>- 4 wunderkind kits
- 20 iPad
- jungle mat
- plastic animals</td></tr>
<tr><td colspan="2">Procedure</td></tr>
<tr><td>Duration

10 mins</td><td>Introduce the activity and explain what a robot is.

A hurricane destroyed the Taman Negara park in Malaysia and an inventory had to be made of the animals that were still alive. The WWF has called in engineers to create rescue robots.

• Bring out students' initial ideas: what is a robot?
• At the end of the debate, state that a robot is 'a machine that functions automatically or in response to a remote control'.
• Ask the students to give examples of robots in their environment (hoover robot, etc.)</td></tr>
<tr><td>5 mins</td><td>Exploring the kit

The pupils get into groups of 5 and each receives a Wunderkind kit. They have to explore the material and indicate what each cube represents.</td></tr>
<tr><td>10 mins</td><td>Bring the students back together to check the robot elements

What did they discover? Institutionalize the sensors (robots use sensors to collect information. These are the pink blocks) and the different blocks (the robots need a motor (blue blocks)). The other blocks are connectors (green) or are used to add visual elements (yellow).

Explanation of the code and how to connect the elements

• There are different elements in the code, each with a different color (blue: motor; yellow: light; orange: sound; pink: trigger; purple: special elements)</td></tr>
<tr><td>10 mins</td><td>Presentation of the mission

You have 10 minutes to create a program for a robot so that it can color-code the right animals to save.</td></tr>
</table>

	Some animals are endangered and have priority in the rescue mission! They must be able to identify if there is an animal by emitting a sound, and display a light if it is an endangered animal. Each group has to identify an endangered animal (for the fastest teams, they also have to create a code that displays a different light for the animal they have to save).
10 mins	**Solving the problem alone** Propose a solution by drawing the code on paper. The students must explain how they intend to create a robot that can avoid obstacles.
15 mins	**Solving the problem in pairs** The teacher creates pairs. The pupils compare their solutions and improve them. They draw their improved solution.
20 mins	**Problem solving in groups of four** The students compare and improve their solutions. Each group receives a robot and an iPad to test their solution with the suggested code.
30 mins	**Animal rescue** **Mission**: Some injured animals have been captured and need to be rescued! The students position themselves around the Jungle mat. The robots must avoid the obstacles to rescue the animals. Each group is given one or more animals to rescue.
10 mins	**Institutionalization** Refine the definition of a robot : • A robot has a body or a processor • they run one or more programs • they are equipped with sensors to interact with their environment without human intervention