Designing and Orchestrating the Classroom Experience for Technology-Enhanced Embodied Learning

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Abstract: The concepts of embodiment and embodied learning, deeply rooted in theories of embodied cognition, are gaining traction in the field of education. New and affordable educational technologies (e.g., motion-based technologies, AR, VR) enable researchers and practitioners to include more gestures and body movements into their learning designs. Yet, while technology-enhanced embodied learning shows positive results during controlled trials in laboratory settings or one-to-one interventions in special classrooms or units, findings are dissimilar when relevant implementations are conducted in mainstream school classrooms. This paper presents the first stage of a design-based research study aiming at implementing an orchestration strategy for technology-enhanced embodied learning, guided by an already published conceptual framework on classroom orchestration. With this study we aim to spark the dialog on classroom orchestration strategies for the successful enactment of technology-enhanced embodied learning in the classroom, highlighting the essential need to consider learning design as it is not a simple process to shift laboratory success to real world learning.

Introduction and theoretical background

The turn of the millennium has witnessed a rejuvenation of interest in embodied cognition theories with an emerging corpus of research on technology-enhanced embodied learning, linked to the emergence of technologies like natural user interfaces, mixed reality and motion-based technologies. However, research is lacking a clear focus on investigating the efficacy of technology-enhanced embodied learning in authentic educational contexts. Technology-enhanced embodied learning has been mainly developed and tested in highly controlled and idealized laboratory settings or in special classrooms using a one-to-one- model of teaching (Georgiou & Ioannou, 2019a). Thus, it remains unclear how students can benefit from technology-enhanced embodied learning in mainstream classrooms with students of diverse abilities and needs.

Integration of technology in the classroom affords opportunities but also constraints in the classroom ecosystem as well as in the learning process. The way teachers manage technology-enhanced classrooms including learning activities and constraints in real-time is known as "classroom orchestration" and it is a crucial aspect, as it directly affects the students' learning experiences (Dimitriadis, 2012; Prieto et al., 2011). As technology-enhanced embodied learning is finding its way into the classroom, understanding the opportunities and barriers of the deployment of relevant technologies as well as issues of classroom orchestration, becomes an important part of learning design (Georgiou, Ioannou, & Ioannou, 2019; Ioannou, Georgiou, Ioannou, & Johnson-Glenberg, 2019). Learning design for technology-enhanced embodied learning requires perhaps new classroom orchestration strategies; however, research is still lacking a model of orchestrating the technology-enhanced embodied learning classroom.

In this spirit, the present manuscript aims to spark the dialogue on how technology-enhanced embodied learning in authentic school classrooms may be successfully implemented. The essential contribution of this work, which is part of a larger design-based research project, is the presentation of the implementation of an orchestration strategy for technology-enhanced embodied learning, guided by an existing conceptual framework on classroom orchestration. First, we sought to analyze the classroom embodied learning experience in order to capture what might be construed as successful orchestration patterns. Second, we aimed to fill gaps in the current understanding of classroom orchestration in technology-enhanced embodied learning environments. Third, we aimed to conduct this study out of a laboratory setting, in authentic classrooms, with all the constraints that a classroom environment imposes. We sought to answer the research question: "*How can a classroom orchestration strategy enable technology-enhanced embodied learning to be successfully enacted in an authentic classroom*?".

Conceptual framework

In this study we adopted Prieto et al.'s "5 þ 3" conceptual framework "characterizing orchestration" (Prieto, Dlab, Gutiérrez, Abdulwahed, & Balid, 2011). The "characterizing orchestration" dimensions of this framework, guided our learning design for the present implementation, informed also by our previous experiences with technology-enhanced embodied learning implementation in the classroom (Georgiou et al., 2019; Ioannou et al., 2019).

According to Prieto et al. (2011) orchestration is […] coordinating a teaching/learning situation, from the point of view of the teacher. Orchestration aims to manage (or subtly guide) the different activities occurring at different educational contexts and social levels, using different resources and tools in a synergic way. Orchestration is […] often guided by a design (in the form of a script or not), that may be flexibly modified during the enactment (automated or not) of the activity, in response to emergent occurrences. The framework presents orchestration in eight characterizing components (Prieto et al., 2011). Five characterizing components provide a descriptive view of orchestration: (a) design/planning of the learning activities, (b) regulation/management of these activities, (c) adaptation/flexibility/intervention (adaptation of the learning flow to emergent events), (d) awareness/assessment of what happens in the learning process, and (e) the different roles of the teacher and other actors. Another three characterizing components deal with key factors describing how orchestration should be done: (a) pragmatism/practice as opposed to TEL-expert, (b) alignment/synergy to the intended learning outcomes, and (c) models/theories that guide the learning orchestration.

Methodology

This study presents the first stage of a design-based research study aiming at understanding "*how a classroom orchestration strategy can enable technology-enhanced embodied learning to be successfully enacted in an authentic classroom*" guided by Prieto's et al. (2011) orchestration framework. The study took place in the context of the INTELed (INnovative Training via Embodied Learning and multi-sensory techniques for inclusive Education) European project [https://www.inteled.org/] (Martínez-Monés, Villagrá-Sobrino, Georgiou, Ioannou, & Ruiz, 2019).

Participants

Participants were 52 students, aged 6-7 years old, derived from three 1st grade classrooms of a public primary school at the Eastern Mediterranean. Students had no prior experience with working in a technology-enhanced embodied learning environment. The students were assigned in mixed-ability groups of four, based on their teachers' knowledge of students' academic background and learning needs, collaboration skills and social relationships. The participating teachers were three females (one in each participating classroom) with 10–20 years of teaching experiences at primary school. These teachers participated in the INTELed professional development program presented next.

The INTELed professional development program

The INTELed professional development program focused on the implementation of technology-enhanced embodied learning in inclusive educational settings. It adopted a cyclical co-design framework organized in two sequential phases: a *Training* and a *Practical* phase. In the *Training phase*, teachers assumed the roles of *"Learners"* and experienced a variety of digital embodied learning games that can be used in technology-enhanced embodied learning. They also assumed the role of *"Designers"* by designing a technology-integration scenario for the enactment of technology-enhanced embodied learning in their classrooms. As part of the *Practical phase* teachers were involved in school pilots, assuming the roles of *"Innovators"* and *"Reflective practitioners"* to transfer in praxis the knowledge gained during the previous phase (Georgiou & Ioannou, 2019b).

Procedures

The classroom learning experience took place in an 80-minute learning session in each of the participating three classrooms. The Learning Stations Rotation Model was adopted, allowing students to rotate through learning stations on a fixed schedule (see classroom orchestration strategy section). The technology-enhanced embodied learning environment made use of the Kinems games. Kinems (https://www.kinems.com/) is a suite of embodied learning digital games for special and general (mainstream) education, supporting students' learning in language and mathematics among others. In Kinems games children can interact with the learning content via hand-gestures and/or full-body movements and receive unobtrusive feedback. The Kinems games were found to be effective in one-to-one sessions with special education students (Kosmas, Ioannou, & Retalis, 2018) and in mainstream classrooms (Kosmas, Ioannou, & Zaphiris, 2019).

Data collection and analysis

Data collection involved post-activity interviews with the participating teachers about their overall experiences as well as videotaped observations from the classroom sessions. These data were analyzed qualitatively and were mapped to the orchestration framework suggested by Prieto et al. (2011). In addition, the participating students were asked to complete a pre-post knowledge test based on the vocabulary of the thematic unit being taught (with a maximum score of 10 marks). The analysis of the pre-post knowledge test was based on a paired sample t-test. Finally, students were asked to complete a post-interventional engagement survey composed of 13 items on a Likert scale 1-4 (Rimm-Kaufman, 2010), which provided insights on their engagement in the learning environment across three subscales: (a) Cognitive engagement, (b) Emotional engagement, and (c) Social engagement. The analysis of the engagement survey was based on descriptive statistics. Below, we present our classroom orchestration strategy as well as our findings from classroom implementations.

Classroom orchestration strategy and evaluation findings

The five main characterizing components, as these were presented in the framework for orchestration by Prieto et al. (2011) were used to guide the design, implementation, and evaluation of the study.

Design planning – codesigning the experience

As part of the INTELed professional development, researchers and educators endeavored to the co-design of a technology-enhanced embodied learning environment for an authentic school classroom with mixed ability students (Georgiou & Ioannou, 2019b). The co-design involved the transformation of the existing classroom setup into a technology-enhanced classroom with technology infrastructure and direct links to the official school curriculum and assessment expectations. Evidence from the participating teachers' interviews provided support for the success of the co-design strategy. Teachers evaluated the co-designing process positively in terms of contributing to the success of the technology-enhanced embodied learning experience. E.g. *"It was successful because it was designed by a group of teachers, not only mainstream teachers but also by a special education teacher and a speech therapist teacher. We were a group of teachers exchanging ideas, while also taking into account our working experience" [#Teacher 1]*

The deployment of a variety of learning activities (technological and non-technological) as part of teachers' professional development were also positively evaluated as contributing factors to the success of the technology-enhanced embodied learning environment E.g. *"I liked the initial stage, when we participated in the professional development workshops on co-designing a variety of leaning activities for embodied learning as well as the support, which we received during the planning of the implementation. These were some positively factors of the implementation." [#Teacher 3]*

Regulation/Management – applying a learning stations rotation model

The *Learning Stations Rotation* Model was adopted (see Figure 1). This model allows students to rotate through learning stations on a fixed schedule. Four stations were set in each classroom.

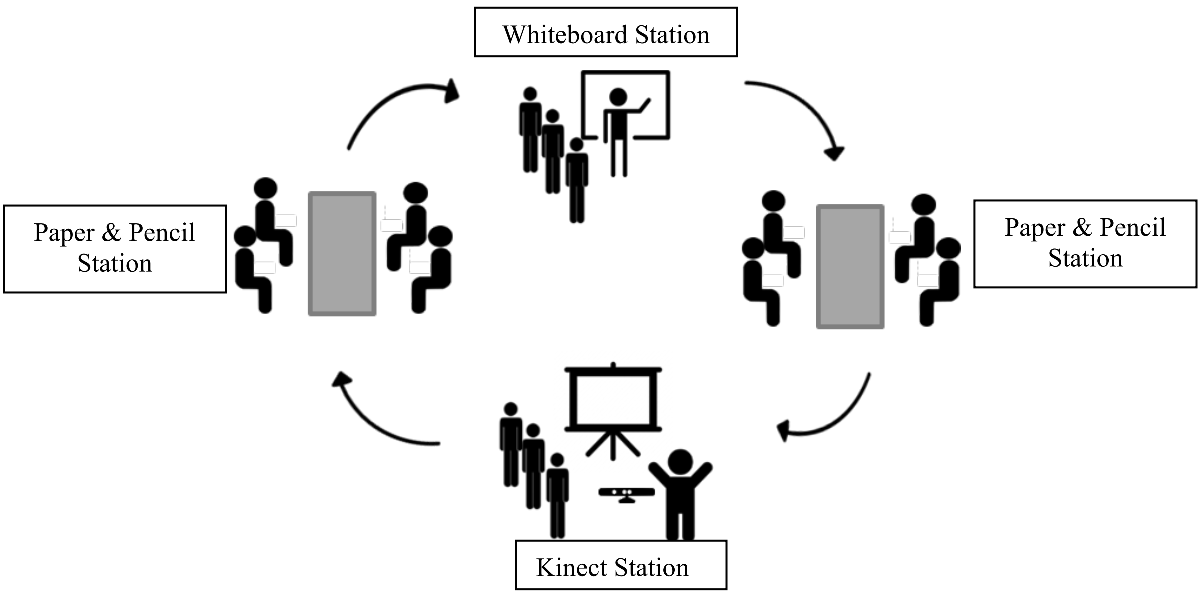

Figure 1. The "Learning Stations Rotation" Model for technology-enhanced embodied learning in the classroom.

Two of the stations utilized technology and the other two utilized conversional paper-and-pencil. The technological stations comprised of (i) a Kinect-based digital game from Kinems (see "Lexis" game at kinems.com/) projected on a portable screen-surface and (ii) a digital game projected and played on the interactive whiteboard of the classroom. Both games aiming at promoting students' language learning –missing letters games – allowing children to practice their skills on word spelling by dragging letters into words, using their hands and arms. The paper and pencil stations were related to word spelling (crosswords, spelling games and word and flash cards matching games). Overall, the stations were conceptually connected, and all the activities built on each other to promote learning in the domain of language, linked to the school curriculum. The setup was informed by (and differentiated from) a previous work which demonstrated that having one technological station for each group was intrusive both for the learners and instructor (Ioannou et al., 2019).

The Kinect-based station was set (a) at the back of the classroom (see Figure 2), letting enough space for students to move when playing as well as isolating the playing group from other students who could intervene and (b) away from windows – as direct sunlight could cause system errors (Ioannou et al., 2019).

At a previous class session, on the day before, the teachers had introduced the use of the Kinect camera (new to the students) and the embodied game (how to grasp items), while also providing time for the children to get familiar with the gaming controls. The experience in the technology groups was scripted – students played in turns, with only one student acting within the playfield, while the others stayed aside to provide support and feedback. In the episode below, the students supported their counterpart by instructing him/her how to use the Kinect game, as the student seemed to be confused, despite the training session. E.g. *A boy came in the playfield. He looked quite confused as on the screen there were two buttons; one to "Continue" and one to "Stop" the game. The members of his team realized that he was confused (even though he did not say anything) and they instructed him:*

> *You have to choose the "Continue" button in order to play.*
> *[The boy moved his hand very quickly and he missed the button].*
> *Have your hand stable on the "Continue" button for few seconds in order to start the game.*
> *[Episode #1, Classroom 1, Station 1: KINEMS game]*

Students in the non-technological stations collaborated on games such as crosswords and spelling games on paper and pencil. The teacher assigned roles to the members of each group in order to avoid fighting over turn-taking and to promote group work. Roles were initiated and adopted by all group members as we can see in the episode below. E.g.

> *Boy 4: (pointing) It's [name]'s turn to be the leader.*
> *Teacher: Ok. Come on [name]. Choose which picture you would like to show to the members of your team. Do you know this vehicle? It is a vehicle which carries liquids. It is a big…*
> *[Episode #3, Classroom 1, Station 2: Paper and Pencil]*

Evidence from the teachers' interviews provided support for the success of the technology-enhanced embodied learning environment with respect to classroom regulation and management, acknowledging the quality of the intervention developed during the co-design phase. E.g. *"The intervention was very well organized. There was added value in technology integration. Students successfully completed all the activities and they enjoyed it too. We were prepared to face all kind of failures, but we did not face any." [#Teacher 2]*

> *"This intervention demanded a lot of preparation. The classroom space sets restrictions. It does not allow you to have more than two technology stations, as you need space and appropriate light. These are some of the main limitations of the classroom reality, which however we managed to overcome, thanks to the professional development and co-design phase". [#Teacher 1]*

Teachers/Other actors – moving from group discussions to quick debriefing at plenary

There was only one teacher in each participating classroom, which demonstrates the possibility to transfer and enact successfully technology-enhanced embodied learning in typical classroom contexts. The teacher rotated through the stations and encouraged peer learning by inviting students to provide feedback to their peers. Informed by previous studies focusing on the integration of embodied learning technologies (Georgiou et al., 2019; Ioannou et al., 2019), the completion of worksheets was also part of the experience, helping to keep the learners focused and on-task along with play. Between students' transitions to the next learning station, the teachers dedicated time to briefly summarize the experience, moving from the small group level discussion to the discussions at the classroom plenary (i.e., quick debriefing). All three teachers acknowledged the importance of the discussion at the plenary, summarizing the conclusions of the task. E.g.

> *Teacher: Ok. Come on [student 1]. Choose which picture you would like to show to the members of your team. Do you know this word? It is a vehicle which carries liquids. It is a big…*
>
> *Student2: It was in our test [meaning pre-test]*
>
> *Teacher: Yes, it was in your pre-test.*
>
> *Student2: Yeah! I didn't write it.*
>
> *Teacher: Your team members will help you. Now you will learn this new word [the teacher speaks to the other members of that team]*
>
> *[name] didn't know it and she didn't write it. But now we will learn it and write it. Can you tell her what vehicle this is?*
>
> *Student 1: Tanker (he reads the word behind the flash card).*
>
> *Teacher: Well done. It's a tanker.*
>
> *Teacher: [speaks to the whole class] Well kids. Can I have your attention please? This is a new word and you will probably find it in your games. Can you recognize what vehicle this is?*
>
> *Kids: Tanker!![The kids from this team were very excited to share their knowledge].*
>
> *Teacher: Well this vehicle is called "tanker" and it carries liquids, like milk or petrol.*

[Episode #4, Classroom 2, Station 2: Paper and Pencil]

Figure 2. The Kinect station for technology-enhanced embodied learning was set at the back of the classroom (left); children playing the vocabulary-game on the interactive whiteboard (right)

Adaptation/Flexibility/Intervention – coaching with flexibility and adaptability

Teacher interview data provided evidence for the important of flexibility and adaptability in the dynamic learning experience. The participating teachers explained that they worked in the classroom as facilitators of students' collaboration. They assumed the role of the coach, *coordinating and supporting students in a real student-centered lesson* (*#Teacher 2), providing help when needed (#Teacher 3), and helping students to stay on track and focused on the task, if they were distracted (#Teacher 1).* All teachers acknowledged the important of flexibility and adaptability during their coaching.

Awareness/Assessment – enabling formative assessment tasks all the way

By creating student-centered activities, the teachers did not resort to transmitting knowledge. The deployment of different tools (technological or non-technological) allowed students to construct knowledge and supported their inquiries. Students' misconceptions were also addressed through just-in-time feedback by the games, by their peers or by the teacher. In this way, there was an elevated awareness of the students' quality of understanding, thus enabling the teacher to orchestrate what concept to focus on when facilitating the discussion at the classroom plenary. All the activities contained formative assessment tasks for the students. E.g. *The children in the group looked for the letters and gave them to their classmate. When they finished the teacher encouraged them to look and evaluate if their classmate had formed the word correctly.*

> *Teacher: What do you think kids? Is this word written correctly?*
> *Student: Yes, but he placed the aerial tramway flash card wrong. It should be placed … [student explains].*

[Episode #5, Classroom 1, Station 4: Paper and Pencil]

The knowledge testing and engagement questionnaire provided evidence for the success of the strategy. A paired-samples t-test indicated significant knowledge gains from pre ($M=6.63$, $SD=2.39$) to post testing ($M=7.75$, $SD=2.32$), $t=4.70$, $p<.001$, with a large effect size ($d=0.85$). In addition, as Table 1 shows, the mean scores for student engagement were well above the midpoint of the scale, especially for cognitive and emotional engagement, demonstrating the success of the adopted strategy in engaging the leaners. Yet, the social engagement variable referring to students' social interactions and collaboration was lower. A plausible explanation is that the setting did not enable students' collaboration to flourish.

Table 1: Students' engagement (*n*=52)

Engagement variables	Mean	SD
Cognitive engagement	3.46	0.66
Emotional engagement	3.30	0.65
Social engagement	2.81	1.04

Evidence from the participating teacher interviews provided further support for the success of the strategy with respect to students' engagement. E.g. *"I believe that the integration of technological and non-technological stations in the mainstream classroom has worked very well. I didn't expect group work in stations to be so successful. There was a learning climate in the class and not just voices and excitement, as initially expected. That learning atmosphere was something I did not expect." [#Teacher 2]*

Discussion

We, next, discuss the major findings derived from this design-based research study. The discussion of our findings is framed by the three characterizing components of how orchestration should be done, per orchestration model of Prieto et al. (2011).

Pragmatism/Practice

Regarding the pragmatism/practice aspect of how the orchestration should be done, a main issue of research on technology-enhanced embodied learning is that few investigations have been conducted in real classroom settings (Georgiou & Ioannou, 2019a). Informed by Prieto et al.'s (2011) orchestration framework, the present study enacted a technology-enhanced embodied learning environment in three school classrooms, trying to overcome the constraints. The constraints included the novel nature of motion-based technologies in relation to usability issues, various technical limitations of Kinect cameras affecting the classroom setup, and the lack of multiplayer affordances in the selected digital games, restricting students' collaboration (only one child at a time was able to play the game). These limitations were augmented by a set of more traditional constraints such as time constraints, classroom management, the different learning pace of each group, and constraints set by the curriculum. Variables concerning the teacher, students, resources, subject, and classroom culture and norms (rules, routines and expectations) had also influenced what and how students learned. The orchestration strategy adopted in this work aimed to present ways to make more effective use of time affording opportunities for students to engage with the curriculum content. We implemented technology-enhanced embodied learning using technological and non-technological stations and even though there was an operational autonomy of learning stations, there was also a conceptual connection among them. Students rotated among the learning stations, to make a good use of the time. The designed learning activities took into consideration the curricular goals and the affordances of the technology.

Alignment/Synergy

Our approach used minimal and manageable resources for implementation. The technology used in the present study allows learners to interact with the learning content via gestures/body movement. In stations, an emphasis was given in promoting reflection and awareness of other teammates. We believe that the integration scenario can be applied even by less experienced teachers.

Models/Theories

Drawing on principles of orchestration, from previous empirical studies and our own empirical work (Georgiou et al., 2019; Ioannou, 2018; Ioannou et al., 2019) we have formulated a set of guidelines on classroom orchestration for technology-enhanced embodied learning. These guidelines are subject to further study, refinement, and empirical validation:

- *Co-design with stakeholders*. The inclusion of emerging technologies, like the embodied learning technologies, in the classroom ecosystem introduces new layers of complexity that teachers have to deal with. This requires exploring the design space to successfully integrate new technologies with current teaching and collaborative learning tools, within the constraints of an authentic classroom (Martinez-Maldonado et al., 2013). Co-design between researchers and practitioners as well as professional development are important if we want teachers to work effectively in implementing embodied learning (Georgiou & Ioannou, 2019b).

- *Create learning stations.* Traditional classrooms have 16 or more students. Therefore, practitioners should aim at having more than one learning stations for different groups working concurrently on the same task. Yet, setting multiple technology-enhanced embodied learning stations is practically impossible. Due to the large projection size and the space needed for students to move, a maximum of two stations could be placed in the classroom. Alternative low-tech stations can be included. Stations with paper-pencil elements can work successfully as they are already integrated in most teachers' routines (Dimitriadis et al., 2013). A learning rotation stations model can be adopted so that all students can engage in the technology-enhanced embodied learning experience.

- *Keep group-size small.* Small-group activity allows the students to take full advantage of the technology-enhanced experience. By having small groups, you can avoid waiting time between turns, which can result in off-task discussions and behaviours (Ioannou et al., 2019).

- *Enable small-group collaboration*. While students clearly have fun with the interface, current forms of embodied learning apps or games are not necessarily "collaborative" yet. Participants seem to engage in too many individual tasks which sometimes lead to unproductive collaboration and limited discussion. To support teamwork, collaboration, scripts may be used to define activities and sequences of activities, while also matching activities to roles and assigning roles to individual learners (Dimitriadis, 2012). This strategy can be used initially and gradually fade as learners develop their collaboration skills internally.

- *Have debriefing sessions.* In a technology-enhanced classroom, students' interactions naturally become playful (Ioannou, 2018), which although beneficial, it can also cause problems in terms of lack of reflection. For example, sometimes the students spend too much time "playing" without communicating their findings or reflecting with their peers. These problems imply that strategies should be applied for reducing these negative effects to let students focus more on reflection and discussion. Teachers should encourage the students to step back from 'play' in order to discuss and reflect on their learning process. Plenaries (or mini plenaries) in the form of debriefing sessions are acknowledged as a widely employed pedagogical technique, relating to scaffolding, orchestration or student/teacher interaction.

- *Scaffold learning and serve the role of the teacher.* Scaffolding can be done by the teachers themselves, by the students, and/or by the technological system. Technology-enhanced embodied learning must purposely be designed to trigger interactions that produce positive learning outcomes. In our design, we employed two of the proposed ideas by Dillenbourg and Fischer (2007) which can trigger specific interactions: (a) placing students in a situation in which they need to engage in effortful interactions in order to build a shared understanding and (b) structuring collaboration by means of scripts. Both strategies worked well in the technology-enhanced embodied learning experience of the present implementation. Overall, the teacher's role in orchestrating learning remained the most important aspect for the successful learning experience. It entails a process of managing the affordances and constraints of the available tools in the most optimal way to support student learning. The teacher's role is to orchestrate the supporting features – the visual cues, the prompts, the questions, the instructions, the demonstrations, the collaborations, the tools, the information sources available, the framing of the learning environment, the group formation, the role assignment for every activity, the number of children involved in the activity and so forth.

Conclusions

To conclude, while researchers often get positive results in investigations about technology-enhanced embodied learning in controlled laboratories settings, findings are not always promising when relevant implementations are conducted in real classroom settings (Anderson, & Wall, 2016; Hung, Lin, Fang, & Chen, 2014). In other words, it is not a simple process to shift laboratory success to real world learning settings. It becomes apparent that the implementation of technology-enhanced embodied learning in authentic classrooms requires special attention to issues of classroom orchestration, referring to the way teachers design and manage technology-enhanced classrooms and the involved activities and constraints in real-time.

This study, which is the initial stage of a larger design-based research project, highlights the essential need to consider new orchestration strategies for the successful implementation of technology-enhanced embodied learning in authentic classrooms. The essential contribution of this work is the presentation of an experience of implementing an orchestration strategy for designing technology-enhanced embodied learning, guided by the published conceptual framework on classroom orchestration of Prieto et al. (2011). The paper presents preliminary evidence for the success of the presented strategy whilst our analysis is on-going. Our findings support that our orchestration strategy can guide the successful design and implementation of technology-enhanced embodied learning in authentic classrooms. The paper aims to spark discussion about strategies for orchestration of technology-enhanced embodied learning experiences and how to test for success. Future work should aim to dig further into qualitative (video) data of classroom implementations to refine this strategy.

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