Computers & Education 95 (2016) 231–238

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

# Streamlined orchestration: An orchestration workbench framework for effective teaching

Lighton Phiri [a, *], Christoph Meinel [b], Hussein Suleman [a]

[a] *Department of Computer Science, University of Cape Town, Private Bag X3, Cape Town 7700, South Africa*
[b] *Hasso Plattner Institute, University of Potsdam, Prof.-Dr.-Helmert-Straße 2-3, Potsdam 14482, Germany*

A R T I C L E  I N F O

*Article history:*
Received 5 August 2015
Received in revised form 23 January 2016
Accepted 25 January 2016
Available online 28 January 2016

*Keywords:*
Computer-assisted instruction
Orchestration
Technology enhanced learning

A B S T R A C T

Effective classroom management is considered a key criterion to making classrooms effective learning environments. Supporting classroom orchestration—the teacher-centric real-time management of classroom activities—is central to achieving effective classroom management. However, the multi-faceted nature of classroom orchestration, its complexity, and general classroom constraints such as time, present challenges for the effective management of the modern-day classroom environment. Though effective, most existing approaches for overcoming orchestration challenges, such as Google Classroom, are arguably ad hoc. We argue that streamlined technology-driven orchestration can be attained through the use of an orchestration workbench, potentially making educators more effective within formal learning environments. Early supporting evidence, from a study involving the use of a prototype orchestration tool, demonstrates the feasibility of organised orchestration and its potential to improve students' learning experience.



## 1. Introduction

Learning scenarios that occur in formal learning environments, such as classroom settings, encompass a wide range of activities and processes that require effective management. The management of these activities and processes, generally driven by the educator, is referred to as orchestration. Though the core focus of orchestration is on pedagogical activities, extrinsic activities and constraints (Dillenbourg, 2013) additionally need consideration.

Supporting educators in such complex and challenging environments could be achieved by simplifying classroom orchestration. However, the multi-faceted nature of classroom orchestration is a daunting process. Not only do teachers need to manage the various in-classroom activities, but also the other most important actor within the classroom—the student. Additionally, the orchestration needs to be conducted in such a manner that critical constraints like time (Dillenbourg, 2013) are taken into account.

Contemporary orchestration is not only challenging, but also ad hoc, resulting in the use of a variety of tools and services. In order to achieve our broader goal of turning the classroom into a more effective learning environment, we propose the explicit streamlining and organisation of orchestration. We premise that streamlined technology-driven classroom orchestration can be attained through the use of an orchestration workbench. The orchestration workbench will provide a

* Corresponding author.
*E-mail addresses:* lphiri@cs.uct.ac.za (L. Phiri), christoph.meinel@hpi.de (C. Meinel), hussein@cs.uct.ac.za (H. Suleman).

http://dx.doi.org/10.1016/j.compedu.2016.01.011
0360-1315/

centralised way of accessing an assortment of integrated tools and services required to perform typical orchestration activities, potentially making educators more effective.

This paper details a proposed approach at appropriately organising classroom orchestration and, additionally, presents experimental results from an early-stage study. The remainder of the paper is organised as follows: Section 2 highlights literature closely related to this work; in Section 3, we outline our claim, and propose an approach to achieve more streamlined and organised techniques for effective classroom orchestration; Section 4 details early evidence obtained during the use of a prototype orchestration tool; and, finally, Section 5 provides concluding remarks and potential future implications of this work.

## 2. Related work

### 2.1. Orchestration

The orchestration term is used within the Technology Enhanced Learning (TEL) field to describe technology-oriented techniques for teaching and learning that place significant emphasis on supporting teachers within the classroom.

Roschelle et al. note that the support is generally focused on challenges associated with technology use within the classroom (Roschelle, Dimitriadis, & Hoppe, 2013). Dillenbourg contends that orchestration has more to do with how teachers manage the complexities of the multi-layered activities conducted in learning space, and notes that multiple constraints existing within the classroom are a major obstacle in effectively managing classrooms (Dillenbourg, 2013).

Furthermore, Dillenbourg, comprehensively classifies activities and constraints in order to highlight fundamental differences between orchestration and instructional design, with the latter being more concerned with intrinsic activities (Dillenbourg, 2013). Tchounikine pointed out that orchestration is real-time while instructional design is a pre-session activity (Tchounikine, 2013). Perotta and Evans, however, provide an argument for why an emphasis on instructional design is insufficient. The central theme to their argument is that more emphasis ought to be placed on more human elements in order to better understand the broader challenges faced during orchestration (Perrotta & Evans, 2013).

Orchestration has been applied in a wide variety of TEL fields, most notable Computer-Support Collaborative Learning (CSCL) (Koschmann, 1996; Dillenbourg, Järvelä, & Fischer, 2009).

Our work is strongly rooted in Dillenbourg's view of orchestration, and also resonates with his notion of using technology to make formal learning spaces effective learning environments.

### 2.2. Technology for orchestration

Integrating technology within the classroom is considered a vital strategy for 21st century classrooms (Saxena, 2013). However, with the exception of mainstream technologies such as interactive whiteboards, LCD projectors and mobile devices such as laptops and tablets, several of these proposed classroom technologies are hardware-based, and generally targeted for learners.

Although GLUEPS-AR (Muñoz-Cristóbal, Prieto, Asensio-Pérez, Jorrín-Abellán, Martínez-Monés, & Dimitriadis, 2013) was designed to provide a potential solution to the orchestration burden, it is specifically aimed at orchestration of across-spaces learning situations. Similarly, GLUE!-PS (Prieto, Asensio-Pérez, Cristóbal, Jorrín-Abellán, Dimitriadis, & Gómez-Sánchez, 2014) is focused on computer-supported collaborative learning. However, looking at evidence obtained from their experiments (Munoz-Cristobal, Jorrin-Abellan, Asensio-Perez, Martinez-Mones, Prieto, & Dimitriadis, 2015), it is evident that supporting orchestration activities presents opportunities necessary to support educators.

Further, there are some notable teacher-centric attempts to turn classrooms into effective learning environments. Google Classroom ("Google for Education: Save time and stay connected") is perhaps one of the most recent orchestration software platforms. Classroom promises to increase teachers' productivity by "weaving together" existing productivity tools such as Docs, Drive and Gmail. Google Play for Education ("Google Play for Education") is another Google initiative aimed at increasing innovation in education by facilitating easy access to approved tools and content in order for teachers to meet individual student needs. While meant to be a generic hub for educational resources, it is in part aimed at facilitating tablet use within the classroom.

That being said, an important point to note is that the use of orchestration technology, though warranted, poses the risk of making the already complex classroom ecosystem (Dillenbourg & Jermann, 2010) more difficult to manage. Sharples (Sharples, 2013) notes that teachers in the modern day classroom grapple to manage its demands and so adding an orchestration technology to this "volatile mix" could potentially worsen the situation.

From what is known, based on available evidence, orchestration is complex, and predominantly facilitated in an ad hoc manner, through the use of specialised tools aimed at achieving a single specific objective.

## 3. Streamlining orchestration

Using the concept of cross-plane integration (Dillenbourg & Jermann, 2010) we view orchestration as a function of the scale of learning activities—individual, group or class—with respect to time. The nature of activities, as shown in Fig. 1, determine the time-frame within which they are undertaken.

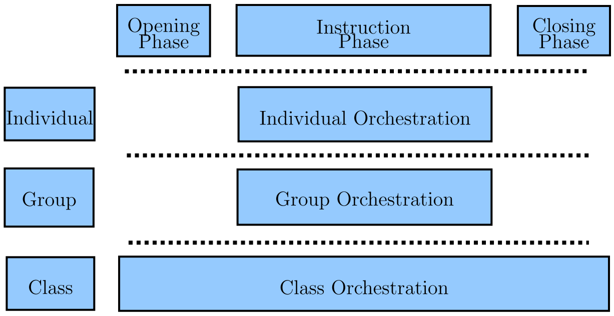



**Fig. 1.** Organisation of classroom orchestration elements.

While the orchestrated learning activities could fundamentally be independent of one another, they could be organised in such a manner that their sequencing is in line with the linear progression of the classroom session. With orchestration having been identified as an important element of interactivity (Beauchamp & Kennewell, 2010), this organisation could also be deliberately designed so as to potentially facilitate interactivity during learning scenarios. Furthermore, in order to overcome timing constraints, the orchestration tool could be designed so that there is seamless integration between the different activities.

More importantly, we propose that three critical aspects—sequencing, time management and activity management—constituting core design factors in Dillenbourg and Jermann's orchestration model (Dillenbourg & Jermann, 2010), need to be adequately addressed in order to achieve streamlined and organised orchestration. These three aspects are outlined below, in Section 3.1.1 to 3.1.3.

### 3.1. *Core orchestration aspects*

Although there are a number of other orchestration aspects (Dillenbourg & Jermann, 2010) at play in the learning environment ecosystem, it is envisioned that focussing on learning activity management, sequencing and timing could potentially result in a flexible and useful 'orchestrable' 'orchestration technology' (Tchounikine, 2013).

#### 3.1.1. *Activity management*

There is a range of activities that take place within the classroom, with the majority of them involving display and visualisation of information. However, there are some activities that might require additional actioning. Thus, there ought to be a reliable way of performing appropriate actions associated with individual activities.

#### 3.1.2. *Sequencing*

Orchestration typically takes place in a linear fashion, with planned activities sequentially performed within set time-frames. While the sequence of activities is in most cases fixed, the sequencing could possibly be performed dynamically; an example here would be swapping start time-frames of a particular course. It is imperative, therefore, that all possible sequencing approaches be taken into account.

#### 3.1.3. *Time management*

Time is a finite resource, and is the most critical constraint during orchestration. Owing to the multiple activities that tend to be allocated individual time slices, teachers typically plan ahead to ensure that time is appropriately allocated. A possible way of efficiently using the limited time would be to devise a non-invasive technique of indicating the time-lapse.

### 3.2. *The orchestration workbench design*

With the widespread successful use of organised environments such as Integrated Development Environments (IDEs) (Wasserman & Pircher, 1987) and Scientific Workbenches (Curcin & Ghanem, 2008), a potentially viable option of streamlining orchestration could take the form of an orchestration workbench platform. The efficacy of scientific workbenches in facilitating workflow-centric tasks makes this proposed approach desirable as classroom activities are typically performed in sequential order. Furthermore, the ability of IDEs in making programmers effective, through the integration and centralisation of various tools and services, further reinforces the viability of the proposed approach. The fundamental idea is to devise a way of integrating various tools and services required to manage the core orchestration aspects in Section 3.1.

The orchestration workbench platform is envisioned as a software environment that integrates and centralises tools and services required to orchestrate a typical teaching session. By centralising access to various tools, the orchestration workbench dramatically reduces the switchover time spent when transitioning to a different tool or service—this would effectively facilitate easier sequencing of activities. The orchestration workbench platform would comprise of core services necessary to

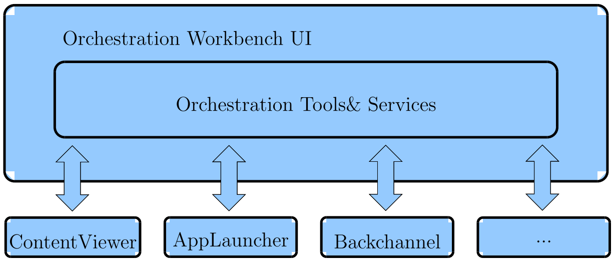



**Fig. 2.** The orchestration workbench platform conceptual design.

enable the seamless integration of tools and, additionally, add-ons specific to individual user needs. Fig. 2 shows a conceptual design of the orchestration workbench architecture.

By considering aspects such as individual educator preferences and availability of requisite infrastructure, various orchestration workbench configuration settings are possible. The orchestration workbench platform may reside on an individual user's local machine and be run as a standalone application. It may also be accessed as a Web service running on a remote machine.

As part of a user initiated configuration process:

- The user sets up relevant configuration details, associated with a module, such as directory location of teaching resources.
- The user selects desired relevant core services.
- The user optionally sets up URL bookmarks for relevant Web services.

## 4. Case study: orchestrating a flipped classroom

As part of an exploratory study, a prototype classroom orchestration tool was implemented in order to manage in-classroom activities for a second year Computer Architecture course.[1] A total of 175 students registered for the four-week long course. The course was conducted using a flipped classroom learning model, comprising of three core components:

- A pre-lecture component requiring students to watch a video lecture and read a reading associated with a particular topic.
- An in-classroom component, segmented into a graded quiz session; a demonstration session and a discussion session.
- A post-lecture component—forming part of the core assessment process—where students were assigned two practical tasks.

In essence, using Fig. 1 as a reference, the three in-classroom activities were orchestrated at the individual level and class level. Table 1 shows the levels of orchestration involved during the in-classroom session. Two factors greatly influenced the activity level: the nature of activities and the class size.

### *4.1. Prototype orchestration workbench tool*

A Web-based prototype orchestration tool was implemented to facilitate the management of the in-classroom activities. The choice of the technology stack was made to take advantage of the browser as a host environment. Fig. 3 is a collage of a lecturer using the orchestration tool during a live lecture session and a screenshot of the orchestration tool dashboard.

In order to facilitate management of the in-classroom activities, the prototype application was implemented with the following features:

- A Countdown Timer feature helped count down to the start of each lecture session. This was done so as to ensure that students quietly settled down towards the start of the session.
- A Demonstration feature was used to render information related to the in-classroom demonstration of the day.
- As with the Demonstration feature, a Discussion feature was used to render a set of discussion questions associated with the topic in question.
- A Quiz feature was used to manage the in-classroom timed quiz session. Using a predefined time slot specified in a configuration file, each quiz question was displayed within that time slot and subsequently faded out.

[1] http://youtu.be/x5s0aENwNMA.

**Table 1**
Varying levels of orchestration in flipped classroom case study.

| Activity | Orchestration | Activity level |
|---|---|---|
| Demonstration | Live hardware demonstrations | Class level |
| Discussion | Interactive class discussions | Class/individual level |
| Timed Quiz | Timed and graded quiz session | Individual level |

- A backend Export feature facilitated the export and subsequent ingestion of the demonstration, discussion and quiz questions into the institutional Learning Management System.

JSON configuration files for the different application features—demonstration, discussion and quiz—had to be updated prior to each lecture session to reflect details for a specific lecture session. The application was then launched via a Web browser running on the machine connected to a data projector. The sequencing of the different in-classroom activities was achieved using a dashboard and menu items associated with the individual activities.

### 4.2. Orchestration tool use evaluation

In order to comprehensively assess the effectiveness of using the prototype workbench as a teaching tool, the lecturer's interaction with the tool was evaluated.

#### 4.2.1. Procedure

To better understand the lecturer's interaction with the prototype during the orchestration of learning activities, the usage of the orchestration tool was evaluated threefold. First, in order to determine improvements to the prototype, periodic informal sessions were held with the lecturer during the study period. Second, direct observations were conducted during lecture sessions in order to observe how the orchestration of activities was conducted using the prototype. And, finally, video analysis on lecture recordings and screencasts—automatically generated by Opencast Matterhorn[2]—was done to establish how the prototype was utilised. Opencast Matterhorn's video segmenter divides captured screen sessions at slide change timepoints. The generated segment timepoints were used to identify the different applications that the lecturer switched.

#### 4.2.2. Results and discussion

The prototype usage frequencies, during the orchestration of learning activities, in all the lecture sessions were noted by manually analysing the Opencast Matterhorn generated segments. In addition, usage frequencies and times for other software applications used during the lecture sessions were noted. This was done to determine the context switching occurring when switching between software applications.

Table 2 shows applications used during all the lecture sessions, the number of times they were used, and their average duration. Table 3 shows the prototype usage pattern across the 11 lecture sessions, compared against the other applications—listed in Table 2.

In general, the prototype was used in all but the last lecture session—an information session centred on non-core module content. On average, it was used 66.72% of the time. The prototype was least used during lecture sessions requiring the use of specialised applications; for instance during session 08, 58.80% of the lecture was dedicated towards referencing content from an external Web application service. In addition, the number of software applications used in some sessions was higher because the activities involved the use of specialised application features not supported by the prototype. For instance, session 02 was a practical Assembler programming session that required the use of a terminal application, a text editor and a simulator.

Also, context switching between software applications occurred an average of two times, with a noticeable period observed during the switchover process. It would thus seem appropriate to devise an easier and more flexible way of launching external applications to reduce the switchover times. As shown in Table 2, most of the applications performed the role of rendering content of different types, such as video content. A mechanism for viewing content of different types would thus be desirable.

### 4.3. Student learning experience study

While the orchestration tool was designed to help the lecturer manage the in-classroom activities, it was imperative that we determine the potential impact of the orchestration tool on another important actor within the classroom—the student. A survey was conducted on the last day of class. The goal of the student survey was to elicit feedback regarding the role the tool might have played in helping organise the lecture session and, additionally, the usefulness of individual tool modules.

[2] http://opencast.org/matterhorn.

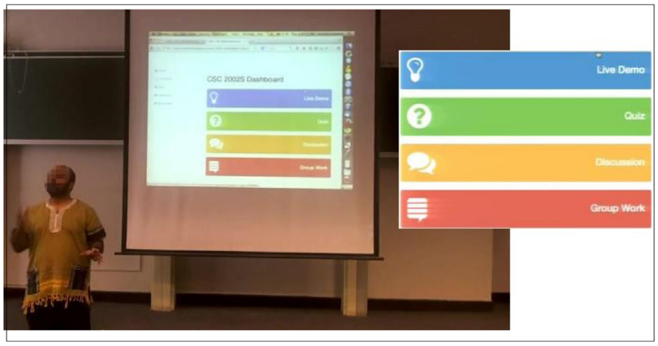



**Fig. 3.** Lecturer orchestrating the flipped classroom activities.

**Table 2**
Usage frequency of software applications in flipped classroom.

| # | Application | Category | Freq. | Avg. Duration |
|---|---|---|---|---|
| 1. | Prototype | Organisation | 10 | 00:30:31 |
| 2. | VideoGlide | Content Viewer | 8 | 00:07:56 |
| 3. | Firefox | Content Viewer | 1 | 00:21:29 |
| 4. | LibreOffice Impress | Content Viewer | 1 | 00:38:26 |
| 5. | Evince | Content Viewer | 1 | 00:00:50 |
| 6. | QtSpim | Programming IDE | 1 | 00:12:47 |
| 7. | Robotic Arm | Content Viewer | 1 | 00:01:24 |
| 8. | TextEditor | Text Editor | 1 | 00:02:07 |
| 9. | VirtualBox | Simulator | 1 | 00:00:58 |

*4.3.1. Participants*

Ethical clearance approval was obtained prior to undertaking the study. The 175 students registered for the course were targeted as potential participants, of which 71 were recruited. 70 of the study participants successfully completed the questionnaire.

*4.3.2. Procedure*

A paper-based questionnaire[3] was designed to leverage a captive audience within the lecture theatre. Demographic information perceived to confound the results was captured using two close-ended questions: the total lecture sessions attended and previous semester marks for each participant. In order to elicit student's subjective feedback on the potential effect of using the tool, a five-point Likert scale was applied to four questions. Specifically, the questions were aimed at assessing role of the tool in helping organise the lecture session; and the usefulness of specific features. Furthermore, an open-ended question was used to capture general comments by participants.

*4.3.3. Results and discussion*

Table 4b shows the results of the demographic distribution of the participants, faceted based on lecture attendance—Table 4a—and previous final semester marks—Table 4b. The graphs in Fig. 4 shows the results of participants' responses to the following statements:

- "The use of the tool helped in organising the lecture sessions"—represented by "Organisation" in Fig. 4
- "The countdown timer before the lecture session was useful in preparing for the session"—represented by "Timer feature" in Fig. 4
- "The listing of classroom activities was useful"—represented by "Activity listing" in Fig. 4

For convenience, only the holistic and, some demographic results, are graphically presented.

The results in Fig. 4a indicate that, overall, the participants felt that the tool was useful and that it helped facilitate the organisation of the in-classroom activities. 52.86% agreed and 18.57% strongly agreed that the tool helped organise the lecture sessions. More importantly most of them agreed that the listing of activities—static sequencing—was useful, with 35.71% agreeing and 17.14% strongly agreeing that the tool was useful. However, some participants had reservations with regards to

[3] http://dx.doi.org/10.6084/m9.figshare.1470182.

**Table 3**
Usage frequency of prototype relative to other applications.

| Lecture | | Prototype usage | Other applications usage | |
|---|---|---|---|---|
| # | Duration | Duration | Count | Duration |
| 01 | 00:46:57 | 00:25:39 | 2 | 00:21:18 |
| 02 | 00:42:48 | 00:26:13 | 3 | 00:16:35 |
| 03 | 00:38:34 | 00:30:00 | 1 | 00:08:34 |
| 04 | 00:39:14 | 00:31:04 | 1 | 00:08:10 |
| 05 | 00:44:16 | 00:32:57 | 1 | 00:11:19 |
| 06 | 00:42:07 | 00:38:53 | 3 | 00:03:14 |
| 07 | 00:43:35 | 00:38:51 | 1 | 00:04:44 |
| **08** | **00:36:32** | **00:14:43** | **2** | **00:21:49** |
| 09 | 00:42:24 | 00:33:19 | 2 | 00:09:05 |
| 10 | 00:38:25 | 00:33:31 | 1 | 00:04:54 |
| **11** | **00:38:26** | **00:00:00** | **1** | **00:38:26** |

The bold signifies lecture sessions where orchestration workbench was least utilised.

**Table 4**
Orchestration survey participants' demographic information.

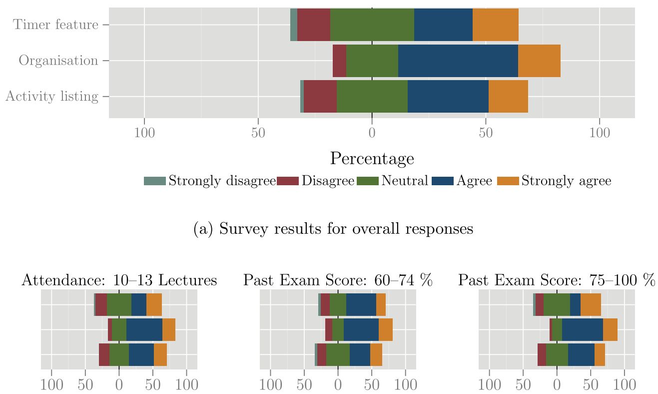
| (a) Lecture session attendance | | |
|---|---|---|
| Sessions | Participants | Percentage |
| 1–3 | 0 | 0.00% |
| 4–6 | 8 | 11.43% |
| 7–9 | 8 | 11.43% |
| 10–13 | 54 | 77.14% |
| (b) Previous semester scores | | |
| Marks | Participants | Percentage |
| 0–49 | 0 | 0.00% |
| 50–59 | 8 | 11.43% |
| 60–74 | 29 | 41.14% |
| 75–100 | 33 | 47.14% |

specific features, such as the countdown timer—37.14% had neutral responses and 14.29% disagreed. It should be pointed out here that the timing feature was only used before the lecture, possibly rendering it irrelevant to some students.

Unsurprisingly, most of the participants attended most of the lecture sessions—10–13 Lecture Sessions—and their responses, as shown in Fig. 4b, do not vary much with the overall results. While both the high and average performing students indicated that the tool helped to organise the in-classroom activities, more of the average performing students found the timer feature useful.

More importantly, results from the pilot suggest that there was minimal impact on the students' learning experience; this is even more evident from some comments made in survey responses; for instance "I did not really notice the tool" and "I found the classroom experience fun".

The first response, above, is especially of interest because it suggests that when compared to the conventional mode of teaching, the prototype tool was perceived to be impact neutral when used to orchestrate learning activities. Ultimately, the




(a) Survey results for overall responses

(b) Survey results for selected demographics

**Fig. 4.** Survey results for overall responses and selected demographics.

use of the tool did not disturb the normal flow of classroom activities. This outcome was also observed as the lecturer used the prototype during the lecture sessions.

## 5. Conclusion and future work

In this work, we presented our claim; that streamlined and organised orchestration could potentially make teachers more effective within the classroom. We introduced our ideas and proposed approach for effective orchestration.

We then provided details on how the potential viability of the proposed approach was explored using a case study. It has been shown that the workbench facilitated a neutral flow of classroom activities, reinforcing the feasibility of such an approach in facilitating orchestration. It has also been shown that an orchestration workbench has the potential to positively impacting the learning experience of learners. 71.43% and 52.86% of participants felt the tool helped organise the session and that the static sequencing of activities was useful, respectively. These positive responses suggest a correlation between the orchestration of learning activities using the prototype tool, and learners' positive learning experience.

As part of future work, we plan to further explore the correlation between the use of an orchestration workbench and positive teaching and learning experience.

## Acknowledgements

This research was made possible through the support of the Hasso Plattner Institute. The authors would like to thank the students who participated in this study.

## References

Beauchamp, G., & Kennewell, S. (2010). Interactivity in the classroom and its impact on learning. In *Computers & education 54.3* (pp. 759–766).
Curcin, V., & Ghanem, M. (2008). Scientific workflow systems – can one size fit all?. In *2008 Cairo International Biomedical Engineering Conference* (pp. 1–9).
Dillenbourg, P. (Nov. 2013). Design for classroom orchestration. In *Computers & education, 69* pp. 485–492).
Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning: from design to orchestration. In N. Balacheff, S. Ludvigsen, T. de Jong, T. A. Lazonder, & S. Barnes (Eds.), *Technology enhanced learning: principles and products* (pp. 3–19). Netherlands: Springer.
Dillenbourg, P., & Jermann, P. (2010). *Technology for classroom orchestration*. In M. S. Khine, & I. M. Saleh (Eds.) (pp. 1–20). New York, NY: Springer.
Google for Education: Save time and stay connected. In: URL: http://www.google.com/edu/classroom (visited on Dec. 10, 2014).
Google Play for Education. In: URL: http://developer.android.com/distribute/googleplay/edu (visited on Dec. 10, 2014).
Koschmann, T. (1996). Paradigm shifts and instructional technology. In T. Koschmann (Ed.), *CSCL: theory and practice of an emerging paradigm* (pp. 1–23). Hillsdale, NJ: Lawrence Erlbaum Associates.
Muãoz-Cristóbal, J. A., Prieto, L. P., Asensio-Pérez, J. I., Jorrín-Abellán, I. M., Martínez-Monés, A., & Dimitriadis, Y. (2013). GLUEPS-AR: a system for the orchestration of learning situations across spaces using augmented reality. English. In D. Hernández-Leo, T. Ley, R. Klamma, & A. Harrer (Eds.), *Lecture notes in computer science: Vol. 8095. Scaling up learning for sustained impact* (pp. 565–568). Springer Berlin Heidelberg.
Munoz-Cristobal, J. A., Jorrin-Abellan, I. M., Asensio-Perez, J. I., Martinez-Mones, A., Prieto, L. P., & Dimitriadis, Y. (2015). Supporting teacher orchestration in ubiquitous learning environments: a study in primary education. In , *8.1. IEEE Transactions on Learning Technologies* (pp. 83–97).
Perrotta, C., & Evans, M. A. (2013). Orchestration, power, and educational technology: a response to Dillenbourg. In *Computers & education, 69* pp. 520–522).
Prieto, L. P., Asensio-Pérez, J. I., Muñoz Cristóbal, J. A., Jorrín-Abellán, I. M., Dimitriadis, Y., & Gómez-Sánchez, E. (2014). Supporting orchestration of CSCL scenarios in web-based distributed learning Environments. In *Computers & education, 73* pp. 9–25).
Roschelle, J., Dimitriadis, Y., & Hoppe, U. (Nov. 2013). Classroom orchestration: synthesis. In *Computers & education, 69* pp. 523–526).
Saxena, S. (Dec. 2013). Top 10 characteristics of a 21st Century classroom. In *EdTechReview*. visited on Dec. 9, 2014 http://edtechreview.in/news/862-top-10-characteristics-of-a-21st-century-classroom.
Sharples, M. (Nov. 2013). Shared orchestration within and beyond the classroom. In *Computers & education, 69* pp. 504–506).
Tchounikine, P. (Nov. 2013). Clarifying design for orchestration: orchestration and orchestrable technology, scripting and conducting. In *Computers & education, 69* pp. 500–503).
Wasserman, A. I., & Pircher, P. A. (1987). A graphical, extensible integrated environment for software development. In *Proceedings of the Second ACM SIGSOFT/SIGPLAN Software Engineering Symposium on Practical Software Development Environments* (pp. 131–142).