The Orchestration Matrix: A Tool to Design Heterogeneous Classroom Ecosystems

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Abstract: Modern classrooms are complex socio-technical spaces where multiple heterogeneous legacy tools and novel technologies coexist. The design and the study of such technological ecosystems (or of single technologies that have to integrate into one such ecosystem) is still under-researched, and we lack established conceptual tools to understand how a learning scenario is orchestrated across such heterogeneous sets of resources, and the role and affordances of each technology in it. In this contribution, we present the orchestration matrix, a simple table-like form that can help technology designers and researchers to analyze an existing technological classroom ecosystem from the point of view of teacher orchestration of a learning scenario, or propose new ecosystems that are (hopefully) more effective.

Keywords: orchestration, classroom technology, classroom as ecosystem, technology design

Introduction

Classrooms have always been complex, both in terms of social dynamics and processes. They are public spaces with their own history, highly immediate, where multiple activities take place simultaneously (Doyle, 2006). And now that technologies are permeating also these spaces, classrooms represent also a complex mix of digital and legacy technologies: pen and paper, laptops, traditional blackboards and tablets and interactive whiteboards and specialized and general-purpose pieces of software running on each of those devices… the list, and its heterogeneity, is almost endless.

As educational technology researchers, we not only strive to find new ways of using technology to learn. We also need to take into account which other technologies already exist there, which may fulfill a similar role, or a complementary one, in a sort of ecosystem where the different new and legacy technologies compete (or collaborate) for teacher and student usage (Zhao & Frank, 2003). However, there is no standard, structured way for researchers (or technology designers) to think about this classroom ecosystem, and how teaching and learning within it can be facilitated or hampered.

In this contribution we present a simple, table-like form to do precisely this kind of analysis, which we call the "orchestration matrix". We have already used it during the design of our own research efforts into classroom technologies, and we hope it can be useful in the context of the 'orchestrated collaborative classroom' workshop, to understand current and future classroom ecosystems, and to ideate new technologies (or new ecosystems of technologies) for them.

The next section reviews briefly the notion of classroom as a technological ecosystem, and other ecosystemic approaches in education and human-computer interaction (HCI). Then, we present the orchestration matrix itself, and illustrate its usage with a real example from our own research. We end the contribution with a few conclusions and projections about future work in this line of research.

Learning Ecosystems vs. Orchestration Ecosystems

The metaphor of socio-technical spaces (such as the classroom) 'ecosystems'[1] has been present in the fields of HCI and education for a long time. Before the turn of the 21st century, Nardi & O'Day (1999) speak of 'information ecologies' as "system of people, practices, technologies, and values in a local environment", and we can even trace the idea further back, to find ecosystemic approaches to interaction design of complex industrial settings, such as nuclear plants (Vicente & Rasmussen, 1992), or even further back, when Gibson's

[1] Some authors use the word 'ecologies' in an equivalent fashion, albeit 'ecosystem' seems to be the most formally correct, when talking about complex systems of living things and the relationships among them. We will use 'ecosystem' throughout the paper, except in those cases in which we directly quote other authors.

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(1979) notion of 'affordances' became widely adopted in HCI. This interest in looking at "technological artifacts as 'species', whose survival is determined by a dynamically unfolding interaction with other species in their shared natural environment", and the practices that emerge in this interplay of multiple actors and pieces of nearby technology, is what Kaptelinin & Bannon (2012) denominate 'the ecological turn in interaction design'. In the field of software engineering, (Bosch, 2009) pioneered the concept of "software ecosystems", as the evolution of software product lines into platforms open to third parties (e.g., Android and its application marketplace), thus supporting associated human activity (social and commercial) ecosystems.

This interest in ecosystems as a metaphor can also be found in the field of educational research, where we can find "ecological approaches to classroom management" (Doyle, 2006), or "learning ecologies" (Brown, 2000) when referring to how the web can change (informal) learning.

Closer to our topic as educational technology researchers and designers, Zhao & Frank (2003) also use this metaphor to talk about technology adoption in schools: basically, within the school ecosystems, computer uses are living species, with teachers acting as 'keystone species', and technological/pedagogical innovations representing the invasion of an exotic species. Luckin (2008) expands on the student side of the equation by proposing a "learner-centric ecology of resources", as the availability of technologies for capturing data, or publishing/creating content increases – which can be exploited for learning purposes if designed adequately.

From the teacher perspective, the notion of the classroom as a complex ecosystem has been retaken recently by Dillenbourg et al.'s (2011) notion of 'orchestration', as the teacher manages the multiple learning processes at multiple social planes and using this ecosystem of resources. They also propose that classroom technologies should be designed, not only taking into account how to best encourage the individual/group learning processes, but also this class-wide teacher orchestration process (what they call the 'third circle of usability'). Unfortunately, as of today there is no widespread model of what the orchestration process entails for the teacher, or what sub-processes may lie within this complex, multi-layered activity.

Hence, we can see that it may be useful, when designing technologies for the classroom, to consider not only our proposed innovation, but also the different resources that teachers and students have at their disposal. Also, it may be useful to consider the role that each of these elements can have in the different (teaching and learning) practices that will take place within this ecosystem: will they be supported by the different technological (or legacy) elements? Will they be hampered by them? Will they collaborate or compete in providing this support?

The Orchestration Matrix

In order to understand the role of the different technological (or legacy) resources of the classroom in the teaching practice, we created the 'orchestration matrix', whose basic principle is to map such resources and the orchestration activities that occur in the classroom. Although no clear model of orchestration activities exists, drawing from existing literature on orchestration and classroom management in general (Dillenbourg, 2013; Doyle, 2006; Prieto, Holenko-Dlab, Abdulwahed, Gutiérrez, & Balid, 2011), we could propose that, at least, the following processes take place (more or less simultaneously) during the run-time orchestration of a lesson: the management of the *content* and learning objectives (e.g., remembering what concepts and curriculum topics to cover today, and delivering the corresponding explanations, etc.), the *awareness* of the ongoing learning processes (including the modelling of students' understanding of the contents), the *logistics* of the classroom (handing out worksheets, logging into a system, moving chairs around for groupwork, etc.), and the self-regulation and *adaptation* of the activities (deciding to cut an exercise short due to lack of time, or improvise an explanation to address an unexpected misconception).

Table 1: Structure of the orchestration matrix

	Teacher orchestration processes			
Technologies	**Content management**	**Modelling**	**Classroom logistics**	**Adaptation & Regulation**
Tech 1	*(How Tech 1 supports, hampers or affects content management, if applicable)*			
Tech 2				
Tech 3				
…				

Then, by creating a table with the different classroom technological resources (including legacy, hardware and software), we obtain the orchestration matrix (see table 1). Within this table, in each cell we write how each element affects the corresponding orchestration process (e.g., if students are using laptops, the awareness of students' progress may only be obtained if the teacher goes behind each student, not from the front of the class; if the teacher is using a web application to have students do individual exercises, the logistics of distributing the task will require the URL to be delivered somehow to each student). When filling in this table, it is important to consider the concrete learning activity taking place; thus, we can have a different orchestration matrix for each pedagogical scenario taking place in a concrete classroom ecosystem. The order of the columns presented in Table 1 has no specific significance, and can be modified.

Illustrative case: Designing Tessellated Battleship

To illustrate this approach, we briefly present how we used the 'orchestration matrix' when designing a recent classroom experiment in a secondary school classroom, in which a new technology was going to be used. We were considering the usage of multiple tabletop computers in the classroom (along with the existing classroom ecosystem that included a projector, a teacher computer, etc.), as part of the evaluation of a new educational game (called 'Tessellated Battleship'). Tessellated Battleship is a review activity about geometry, coordinate systems and directed numbers (the activity was designed for 11-12 year old students), all topics within their mandatory curriculum. This experiment was framed within a larger project in which we explore the effects of paper (and especially, augmented paper technologies) in classroom orchestration (1).

Figure 1 shows the actual orchestration matrix used, with the different technologies in the ecosystem (including the tabletops we were introducing, but also existing elements such as the wall display usually present in the classroom) represented as rows on the left side. Thinking about the learning scenario we had in mind (basically, a collaborative game in which different groups of students try to stop the advance of a virus infection using lasers with different geometrical forms, in a similar fashion to the classic battleship game), we filled in the role that we envisioned for each technology (e.g., the wall display would help in the classroom logistics by displaying the current phase and the overall state of the game; orchestration cards were to be used to facilitate disciplinary measures like freezing the game, etc.).

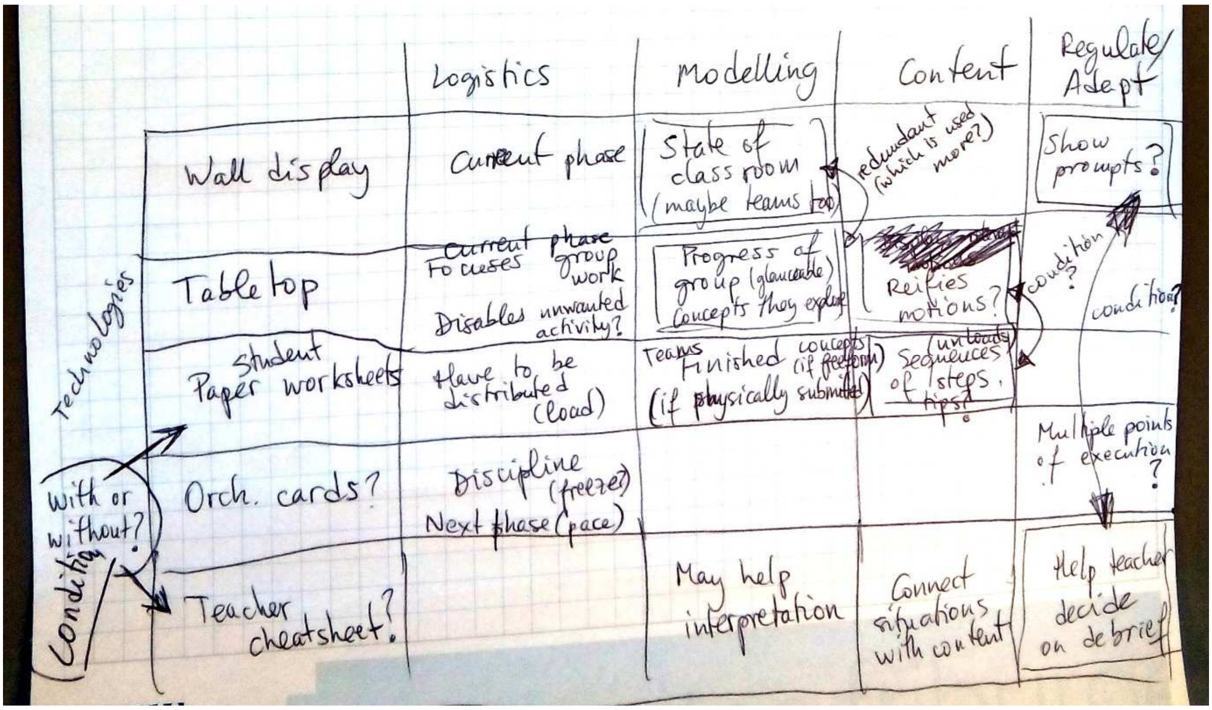

Figure 1. Example of orchestration matrix during the 'Tessellated Battleship' classroom experiment design

In this orchestration matrix example we can also see its usage as we were considering several variants in the design of the classroom ecosystem, and in the orchestration of the scenario (represented by the arrows between different cells). For instance, in the right side of the figure, we can see how we were considering two different ways of aiding the teacher in the regulation/adaptation of the lesson: either by showing prompts at different times on the wall display, or by providing teacher with a ‘cheatsheet’ of prompts and adaptations to be performed at different times during the lesson.

It is worth noting that, in this example, the designer was operating alone, considering especially how the different research questions (e.g., what is the role of augmented paper elements on the orchestration load of the teacher) could be investigated by modifying different elements in the ecosystem. Later on, the different alternatives that emerged while brainstorming with the orchestration matrix were discussed with the teacher, helping shape which ecosystem variations were feasible within her particular classroom.

Conclusions and the future

We have presented here a new way of organizing information about the technology in a classroom ecosystem, aimed at helping researchers and designers better understand their use in classrooms, from the point of view of how each of the present pieces of technology affect the orchestration processes. As presented here, the focus is on classroom orchestration (often performed by the teacher) in run-time. However, this table form could be extended in the future to cover other orchestration processes (such as the activity preparation beforehand or the post-hoc evaluation of the learning process). It could also be expanded to include the student view of things (e.g., how the different technologies affect the learning processes of students), for example using Bloom's (1956) or Krathwohl's (2002) taxonomy of learning activities. Also, this classroom-centric design tool could also be expanded to take into account the learning that happens across different contexts (e.g., in a field trip, in a museum, etc.): these different ecosystems could be designed using a separate table, or by expanding the table to include non-classroom technologies and moments. All these additions, and its use and refinement in real other research efforts, can help in having a more global understanding of what will happen in the classroom ecosystem when all these processes interplay.

Endnotes

(1) http://chili.epfl.ch/miocti

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