Trends in orchestration. Second research & technology scouting report

Pierre Dillenbourg

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Trends in Orchestration

Second Research & Technology Scouting Report

Edited by
Pierre Dillenbourg

SEVENTH FRAMEWORK PROGRAMME

STELLAR

Amendment History

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0.1	21/1/2011	P. Dillenbourg (EPFL)	Synthesis based on papers from the Stellar community
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Trends in Orchestration

Second Research & Technology Scouting Report

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Executive Summary

The technological evolution in schools has transformed the way teachers have to manage technology-enhanced classrooms. This new form of management is often referred to as 'orchestration'. In former times, learning technologies were mostly self-contained environments, running on a single device. In the last decade, *integrated pedagogical scenarios* have emerged. They integrate activities at *multiple social planes* such as individual reading, team argumentation and plenary sessions. The integration of these activities occurs both at the pedagogical and at the computational level (data flow between activities). These scenarios articulate activities with and without digital technologies. The digital ones do not rely on desktops/laptops but also on smart phones, PDAs, digital tabletops, interactive whiteboard, interactive paper, sensors networks, etc. The real time management of such complex ecosystem cannot and should not be automated. It requires, and that's a positive point, an *active teacher* able to intervene at any time to change activities, to modify the timing, to re-compose groups, to prompt unproductive students and to maintain expectations.

The role of an energetic teacher, managing multiple actors and multiple tools, evokes the image of an orchestra conductor. This is probably why 'orchestration' spread quickly as a metaphor; it intuitively conveys a certain vision of classroom management. One could argue that there is a touch of von Karajan in every talented teacher. However, this metaphor meets criticisms. In music, the term refers to the composer's activity, i.e. to (re-)writing a score, namely optimizing the distribution of different voices over different instruments. It does not refer to the time when the orchestra performs. In TEL, orchestration was not meant to refer to the instructional design phase but to the enactment of a pedagogical scenario. In software engineering, the term is used in a way that is compatible with the musical meaning. Should our community further elaborate the metaphorical mapping between the musical field and classroom management? Or, conversely, should we simply consider 'orchestration' as a label to stress a phenomenon that has been somewhat neglected in TEL? Both opinions are expressed in this document. Nevertheless, despite divergences, contributors do more or less converged on several basic points (that have been discussed in the workshop that concluded this Stellar work):

Integrated scenarios. We shared a certain vision of a learning based on scenarios that combine multiple planes of activities (individual / group / class / community) and multiple tools (digital or not). This is reflected by the emergence of a notation (social planes X times) that amusingly looks like a musical score.

Empowering teachers. The real time management of these integrated scenarios is highly demanding for teachers. Hence, the design of TEL environments should facilitate this management. Empowering teacher does not mean more lecturing. It means enabling the teacher to have the lesson "in his hands".

Flexibility. The previous point requires technologies that have the sufficient flexibility to allow teachers to change them on the fly. At the heart of orchestration lies the natural tension between the pedagogical decisions taken at the design time and those taken at run time.

Practicalities. The enacting teacher faces many practical problems that have not received attention in TEL, such as managing time and discipline. Of course, instructional design should primarily focus on effective learning activities, but these small problems play a important role in determining if teachers will use a TEL scenario in a sustainable way. The balance between the attention to be paid to learning mechanisms and to these logistics aspects is a point of disagreement among the contributors.

Constraints. Many practical issues concern the time and space constraints of the classroom. The attention paid on the physicality of the classroom is quite new in TEL, where virtual spaces received most attention in the previous decades. However, some authors consider the 'extended' classroom, i.e. not only the physical classroom but also field trips, museum visits and on-line activities.

These elements consolidate each other well enough to be able to claim that they together constitute a specific approach to TEL. They do not constitute an articulated theory. In the absence of such a theory, 'orchestration' could simply be viewed as the flag of the TEL approach described by these 5 points.

This deliverable does not preclude that orchestration applies to informal education or to on-line virtual spaces: orchestration has a specific meaning in the classroom context; it could be extended to other contexts, probably with a different meaning. In anticipation to diverse uses of the word, it may be safe at this point to refer to classroom orchestration.

1. Method and contents

This deliverable has been elaborated as follows.

- In October 2010, P. Dillenbourg collected papers within the STELLAR community from which he wrote a first report on orchestration in January 2011
- This first report has been discussed during an on-line meeting with a group of STELLAR WP1 delegates. We concluded that it would be difficult, and probably not interesting, to define an ecumenical position.
- Therefore, P. Dillenbourg wrote a position paper, presenting a personal viewpoint, and distributed it through the STELLAR website as well as by other means.
- Several scholars wrote a response to the position paper, included in this document. Some authors belong to the STELLAR: Mike Sharples (UK), Frank Fischer and Ingo Kollar (Germany), Pierre Tchounikine (France). Others authors provided an external viewpoint: Yannis Dimitriadis, Luis Pablo Prieto & Juan Igancio Asienso (Spain); Jeremy Roschelle (USA), Chee.Kit Looi, (Singapore), Miguel Nussbaum & Anita Diaz (Chile).
- P. Dillenbourg compiled the answers and added a synthesis as well as a technological section.
- The majority of the authors convened during workshop on classroom orchestration, organized as a pre-conference event to the Computer Supported Collaborative Learning conference in Hong-Kong, in July 2011.
- A synthesis of their responses, combined with a synthesis of the workshop is presented at the end of the document.
- The final section addresses the question from a technology viewpoint: are there technologies specific to classroom orchestration. Here, the distinction proposed by P. Tchounikine between orchestration and orchestrating technologies is especially relevant.

Several other members of STELLAR contributed by the comments: Nicolas Balacheff, Fridolin Wild, Ulrike Cress, Denis Gillet, Rosamund Sutherland, Christian Voigt, Christian Glahn. This text also benefited from discussion with Ulrich Hoppe, Patrick Jermann, Frédéric Kaplan, Hamed Alavi, Sébatien Cuendet, Guillaume Zufferey, Quentin Bonnard, Son Do-Lenh.

2. Position paper

“Design for Orchestation”, Pierre Dillenbourg, EPFL, Switzerland

Orchestration refers to how a teacher manages in real-time multi-layered activities in a highly constrained ecosystem. I claim that this concept is useful for increasing the impact of learning technologies on educational systems

Why?

In “technology *enhanced* learning” (TEL), the middle word raises the expectation that technologies improve learning. How? There are three roads. The long road postulates that a deeper understanding of cognition, learning and teaching will eventually improve education. A second road postulates that technologies will radically shake the educational system, by setting up a new relationship between people and knowledge. The third road aims at impacting directly education through the development of new approaches, methods and tools. We could respectively call them the Piaget, Illich and Bloom roads. Orchestration belongs to the third road: On the Bloom-TEL road, it begins a significant bend due to two main phenomena that happened during the last decade.

The first phenomenon is integration, which appeared especially in the field of computer-supported collaborative learning (CSCL). Practices evolved from purely collaborative tasks to scripts that include individual learning, teamwork and class-wide activities (lectures, …). The same for other TEL sectors such as inquiry-based learning that integrates argumentation phases. Some of these activities are based on computers, some not at all and some are in the middle; some are presential and some are on-line. Times of pedagogical orthodoxy are over. From a technical point of view, different tools (simulations, microworlds, quizzes, wikis,…) are integrated. Due to this integration, TEL evolved towards open and rather complex scenarios that have to be managed on the fly by teachers (Dillenbourg & Fischer, 2007).

The second phenomenon is the technological spread. We used to claim that TEL impact will occur the day when conditions X,Y,Z will be true. In Europe, these days are today: computers are available at home and, to some extent, at schools; Internet access is ubiquitous; teachers use these tools in their everyday life… but yet, not in schools. Our “tomorrow” alibi is out of date. If these conditions are almost met while our tools are stills poorly exploited, there is something wrong in our approach. I claim that our tools are underused because their design neglects the numerous constraints that teachers have to cope with.

The prototypical example of orchestration concerns a course of trigonometry conducted by a teacher for a class of 23 teenagers present in a classroom. The word ‘teacher’ refers to a person that it *responsible* for the fact that some other people learn (as Hoppe puts it). The word ‘class’ is important for many reasons, a class is a social entity, but overal because many difficulties in orchestration are related to the number of learners to be managed.

The word ‘classroom’ stresses the physicality of orchestration. Of course, a virtual classroom also has to be orchestrated but my main focus is the traditional school classroom with chairs, tables a blackboard or whiteboard and a teacher. This is hardly original, but it nevertheless concerns hundreds of millions of kids.

The kernel and rings

Orchestration expands instructional design. So far, it was mainly about designing the core instructional sequence, the lesson plan, the scenario, the script, the strategy, etc. I deliberately use a neutral word, kernel (Figure 1), to include all of them, independently from their educational flavor. If the learning objective is to acquire new concepts, the kernel will include some induction and discrimination activities. If the goal is about scientific laws, some form of hypothetical reasoning should be triggered by the designed activities. Kernel design has to solve a crucial and difficult equation with several parameters: mainly the learning objectives, the learner’s characteristics and the learning processes.

The kernel includes the regulation of learning processes: monitoring the learner’s activities (student modeling) and adapting instruction (individualization) if needed. The dream of (intelligent) educational systems was that this regulation could be fully encapsulated in the environment. This is not possible with the scenario includes non-computerized activities.

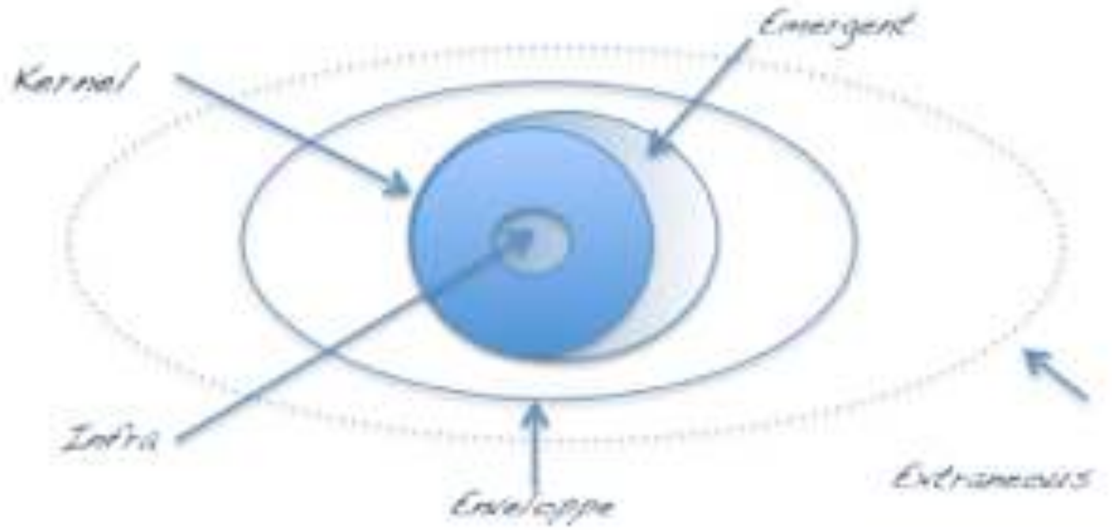


Figure 1. Educational design concerns the kernel; orchestration is about the rings

Orchestration starts from here. It concerns many things happening around the kernel:

- Emergent Activities (designed but contingent): The kernel includes activities that are not completely predictable, namely all the activities that build upon what learners have produced in earlier phases of the scenario. Examples of ‘debriefing’ activities are presented hereafter. These activities have been designed, they are a part of the kernel, but require elaborating in real time from what is available.
- Envelope activities (non designed but necessary): Classroom life includes activities that do not belong to the kernel but which are usually added by the teacher because

they consolidate the kernel. One example is to ask students to copy into their personal files what is left on the blackboard. This time consuming activity is not only a tradition, it answers to a constraint (see hereafter): to leave tangible traces of the learning activities. A difference between the kernel and the envelope is that reaching the objectives is not the end of the story. Often, the same content will be covered along several sessions, include summaries, homework, feedback sessions. Evaluation is part of the kernel, but it is followed by multiple evaluations (end of a module, chapter, semester) that, together with revisions and syntheses, form the envelope.

- Extraneous events (unavoidable): Classroom life is full of events that do not belong to the kernel, for example: (i) The kernel is a script with 3 complementary roles but one team member drops out the course at mid term (ii) The kernel is about guided discovery activities but the first kid who found the solution was so proud that he shouted it out loud for the whole class (iii) Sophie was sick last week and missed the first half of the kernel. These 'extra' are not specific to TEL, but TEL increases their frequency (bugs, network failures, etc.) and makes adaptation more difficult.
- Infra activities (non designed but necessary): Some activities are not a proper part of the pedagogical design but are necessary to run the scenario: finding the right document, opening books at the right page, remembering one's password or moving chairs before teamwork. These logistic issues interfere with the kernel, by wasting precious time, and if they fail they can spoil the most perfect kernel design.

These rings are clouds of things we carefully control when conducting experiments. In the real world, this is impossible and may explain why experimental results are rarely reproduced in the real schools. A pedagogical method that is proven effective does not necessarily turn into a pedagogical method about which a teacher could say: "**it works well in my classroom".**

My point is not that these elements belong to the reality of school; anyone knows that. My point is that our community won't have a major impact without turning them into design principles. We cannot neglect the kernel but have to consider these rings, even if some issues mentioned seem to be just about the logistics.

Constraints

Another way to dissociate the kernel and the rings is to analyze the constraints from which they result. The kernel design has to cope with essential constraints:

- The curriculum (what): A teacher is supposed to help his students to reach the objectives specified in the curriculum. There has been a trend in TEL to design environments that target skills that do not belong to any curriculum, simply because they suit our research agenda. Teachers are not free to teach whatever they like: it's not surprising to get low impact if researchers ask them to teach their pet topics.
- The contents (what's inside): The intrinsic properties of the skills and knowledge to be taught shape instructional design by mapping categories of skills (cognitive taxonomies) with learning activities and/or by analyzing the epistemology of the contents (didactics).
- How people learn (how): The human brain is a main design constraint. Educational psychology feeds design with affordances (e.g. the positive effects of pre-structuring

scaffolds) and constraints (e.g. the limits of working memory). This includes a difficult constraint: raising and sustaining motivation.

- The learners (who): Laws on aptitude-treatment interactions revealed that the effectiveness of instruction depends upon individuals' learning styles. This work was methodologically elegant but poorly generalizable. The main source of failure in schools is a simple learner feature: missing pre-requisites.

Designing for orchestration means paying more attention to a broader set of constraints.

- Assessment constraints: Beyond the usefulness of formative or even summative evaluation, schools are driven by the need to provide grades. A good pedagogical scenario may be abandoned if this is not the case. For instance, a common reason for which teachers reject collaborative projects is the difficulty to give individual grades.
- Time constraints: A common reason for which teachers reject constructivist methods is the time they take within the day schedule. Design for orchestration must minimize time. Moreover, time is often segmented into slices of 50 minutes: orchestration has a lot to do with time management.
- Discipline constraints: Formal education systems expect their teachers to be in control of their students, to have a reasonable level of discipline: some life, but no chaos, no violence.
- Energy constraints: How much energy does the scenario require: preparation work, time to provide feedback, etc. If we design for heroes, we lose scalability and sustainability (heroes get tired).
- Space constraints: Is there enough space in the classroom to set up activities, is the classroom layout compatible with the type of interaction that will be triggered or to the work format (e.g. teams).

I could continue the list of constraints: finances, teacher's personality, safety, school culture, etc. I don't want to develop yet another metaphor here, but from a physics viewpoint, the rings seem a response of the system to the pressure or the friction created by these many constraints

Design for orchestration

How can we design environments that facilitate orchestration? I have no general theory but present examples from which design principles could be elaborated. Let me start with examples from colleagues.

(1) An early example was given by Roschelle and Pea (2002): when a student walks across the classroom to share PDA data by infrared instead of sending them wirelessly, this publicly visible walk provides the teacher and other students with the awareness of the actual dataflow. The kernel (math problems) would be the same in a wireless version but the orchestration is different.

(2) In the work of Nussbaum et al. (2010), about 40 kids interact with a mouse on a single display. Each student owns a tiny subset of the display area, as small as a phone display. The same activity could be conducted on a PDA: the kernel would be the same but the orchestration would be more difficult. Imagine how difficult it is for a teacher

in front of 40 kids having each their own PDA if he wants to get their attention for a collective explanation?

(3) Another example is Nussbaum's notion of 'silent collaboration'. About 20 students build a grid collaboratively: the kernel is that each student is responsible for a cell of the grid and they have to exchange objects in such a way that all objects find their right place. A discussion between 20 students would be chaotic; hence the system allows proposing and exchanging objects without conversation. Of course, CSCL is about triggering verbal interactions, but the classroom constraints led the designers to develop a mechanism that is probably cognitively as demanding but without the noise drawbacks. The kernel is (almost) the same but its orchestration is different.

Let's move to how orchestration was implemented in our technologies. We developed several scripts. They are scenarios that impose constraints on the collaboration in order to foster certain socio-cognitive activities

(4) 'ConceptGrid' is a variation of the JIGSAW script (Dillenbourg & Hong, 2008): 3 students read different papers in which 9 concepts are present; they have to define them and to assemble definitions in a concept grid, which is a kind of simplified concept map. When we used this script, if a student dropped out the course, his two peers immediately complained that they had more papers to read. To cope with this problem, we replaced the missing member by a 'joker': If role-X misses in team-N, this team can borrow the definitions produced by the student playing role-X in any other team. This orchestration act saves the kernel.

The most spectacular moment of orchestration is debriefing, when the teacher drives the students' reflection about their productions.

(5) In the last phase of the ConceptGrid script, teacher asks students to explain their definition and justify why they connected some concepts, gives feedback, relates concepts to theories, etc. A tool supports this debriefing: the teacher can navigate by grid (each team produced a grid), or by concept across the different grids, etc. Before the debriefing session, the teacher may highlight the interesting elements (e.g. frequent mistakes) with different colors to find them rapidly during his lecture.

(6) ArgueGraph is a CSCL script (Dillenbourg & Hong, 2008) in which students answer individual questionnaires on the basis of which the system builds a map of students' opinion and form pairs of students with opposite opinions. Pairs have then to answer together the same questionnaire. The script ends with a debriefing session. The teacher uses a debriefing tool in which all elements introduced by individuals and pairs to justify their answers are listed for each question. The teacher may navigate question per question, answer per answer. He asks students to further explain their choice, reformulate their arguments with proper concepts, relate them to theories, etc. The system also displays who has changed opinion between the individual and the collaborative phase: asking students what made them change their minds is a good orchestration trick.

A more recent system, Tinkerlamp, (Figure 2) is an augmented-reality tabletop simulation for training apprentices in logistics (Zufferey et al, 2009). Swiss vocational education follows a dual approach: apprentices work 4 days per week in a company and 1 day per week at school. Apprentices in logistics have to learn how to optimize storage surfaces based on the frequency of product sales, how to manage their stock, etc. Teams build the mock-up of a warehouse by placing shelves on a table. The system includes a camera and a projector. It recognizes the visual markers on the shelves, computes a model of the warehouse and displays information on the table such as shelve contents and forklift movements.

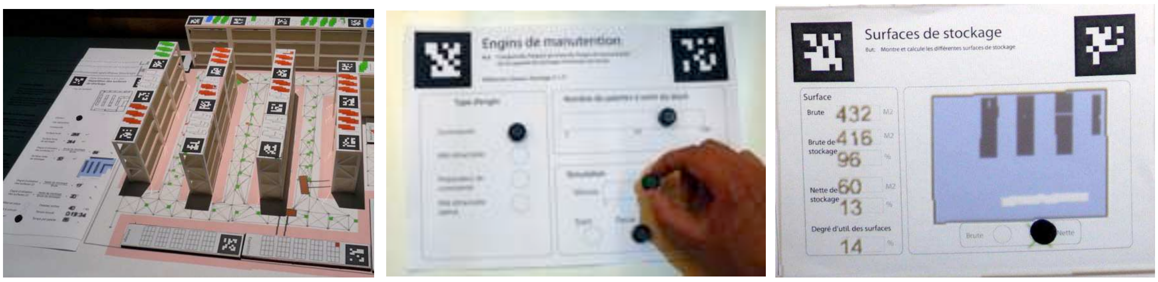


Figure 2. Input (middle) and output (right) sheets for a tangible simulation (left).

(7) The tangible interface enables students to explore many warehouse designs, but tinkering is not learning. Learning requires reflective activities that are orchestrated by the teacher with paper sheets. One student per team (usually 4 teams per classroom) copies its warehouse layout and performance values by passing a pen on the information project on the paper sheet. The teacher asks them to bring this sheet to the blackboard and to copy the information (Fig. 3 left). The teacher then questions them to explain why a design was better than another (Fig. 3 right). While a client-server architecture would display the same data faster, this media discontinuity affords smooth transitions between teamwork and class activities.

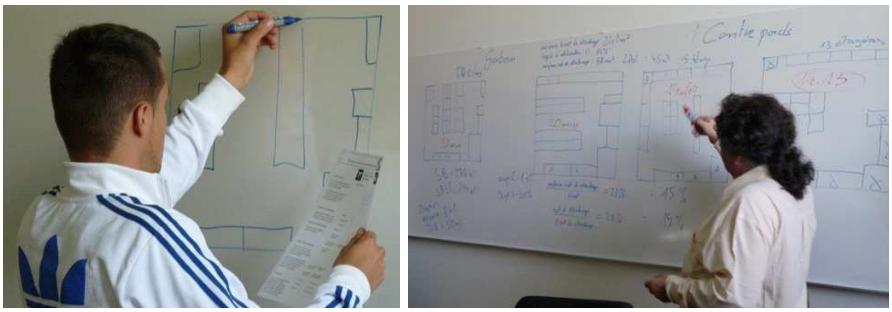


Figure 3. Teams report results by using sheets. The teacher compares the solutions.

Paper facilitates orchestration because **orchestration is about managing the workflow and that paper makes this workflow visible**, concrete, easy to refer to and to manipulate, as further illustrated below.

(8) Homework is an example of the envelope ring. During school time, students have to save the 4 warehouse layouts they have constructed on the table. The system prints a

sheet with these 4 layouts (Figure 4 left). Students have to bring them to their workplace, compare them to the warehouse where they work (based on some criteria) and bring the sheet back for the next course.

(9) Curriculum relevance is turned into a concrete object. The logistics curriculum has the form of an A4 binder produced by the professional corporation. We inserted A4 sheets (Fig. 4, right) that include all information the system needs to set up an activity. To run an activity defined in the curriculum, the teacher opens his binder, selects a sheet and places it partly under the lamp. After the lesson, the teacher can annotate this sheet for the next year (teaching is a repetitive job!), make copies for colleagues, etc.

(10) A well-known problem in learning from simulations is that students can run a simulation many times without much reflection (De Jong & van Jooligen, 1998). Since our tangible simulation is very playful, this risk is especially high. We therefore developed the *paper orchestration keys (POKs)*: teams cannot run the simulation without showing this key to the camera. The standard scenario is that the teacher has the key when apprentices call him to run the simulation. Before giving the key, the teacher asks them to predict if the warehouse performance (average time to move a box from the shelves to the truck) will be higher or lower than in the previous run, and why. The key empowers the teacher in his management of teams and makes the scenario easy to orchestrate: the teacher may decide to leave a copy of the key to a good team, to give a key to all teams, to take it back, etc. This could be achieved with some options in the software interface but the paper key makes these decisions visible for all actors.

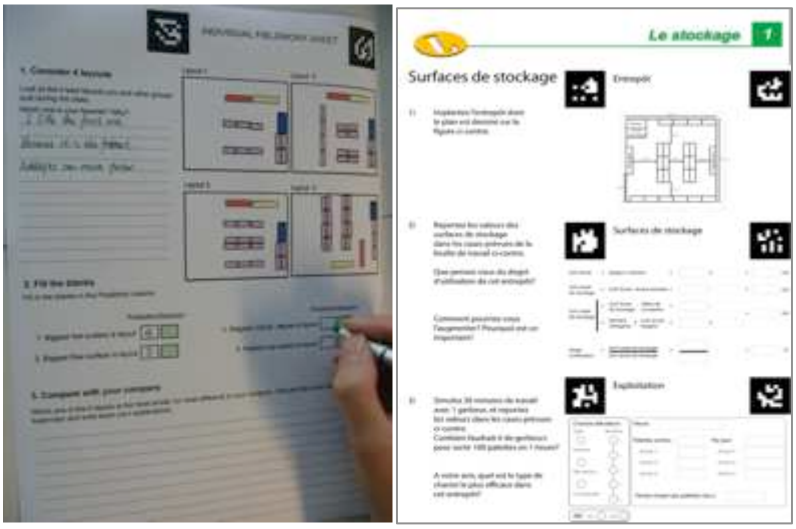


Figure 4. Left. The classroom activities produce homework sheets. Right: Curriculum sheets

(11) POKs are also implemented in an augmented reality environment (Figure 5, left) that uses paper to teach geometry in elementary schools (properties of triangles/quadrilaterals, surfaces, angles, symmetry axes,…). The learning activities use paper sheets as tangible objects: paper-made polygons can be rotated, folded

(axes), cut, etc. Since these are the core manipulations for understanding geometry, they belong to the kernel. Teachers use POKs to select various options that change the activity on-the-fly: they may show a card to the system to display the length of each segment; they may decide to provide kids with quantitative cards (e.g. measuring the surface) only after they qualitatively understood the notion; they may distribute different cards to different members of a team to define roles, etc.

(12) The same approach is used for training apprentices in carpentry (Figure 5, right), They have to learn technical drawing (the relationship between a 3D object and its 3 orthogonal projections). A script is that a team "freezes" tow out of the 3 orthogonal views and gives the bocks to another team that has to assemble them in a way that matches frozen views. A POK presented by the teacher displays (in red) a scaffold for the second team (the difference between their current construction and the one they have to produce), Another POK displays construction lines: experience show that this key should not be given too early, otherwise it short-cuts the targeted reasoning.

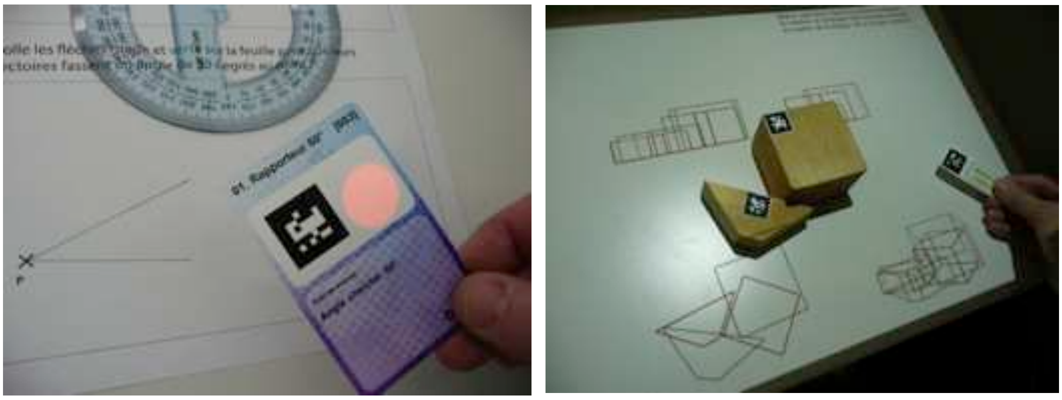


Figure 5. Left: this POK displays feedback. Right: this POK provides scaffolds.

Distributing sheets, collecting them, storing them or annotating them are common practices in schools ecosystems. Paper-based computing builds upon these practices to facilitate orchestration. The last examples concern another key part of orchestration: how to facilitate the monitoring of learners activities without overwhelming teachers with detailed student models?

(13) In Nussbaum's environment, the central display is divided into 40 squares and each square contains the activity of one learner. This square becomes shaded, covered by a sleeping icon, when the student is not active for a certain time. The teacher has also access to a more detailed tracing tool, but the simple fact of seeing globally who is active or not facilitates classroom management. Doesn't a good teacher permanently scan the classroom, visually, to update his classroom model?

(14) Some design features may be detrimental to this visual scan. Let us illustrate this with the design of the Tinker Lamp. In the reported experiments, the teacher placed four lamps (Fig. 6 left) in the classroom. Each lamp had a different color, which of course does not change the learning activity (kernel) but changes the management of multiple teams, since the teacher may easily refer to them.

(15) In new designs, the projector is placed on the table and a mirror above the table reflects the image (Fig. 6 middle and left). Their designs induce different orchestration processes. The black model prevents the teacher from seeing in a glance what students are doing while the white model does not break the line of sight. The white model is better suited for cases where several TinkerLamps are used in the same classroom: the black model would deteriorate visual monitoring. Conversely, elementary classrooms often have a corner with a bookshelf, a sofa and a computer-table The black model allows a team to work discretely in its space without disturbing or being disturbed too much by the rest of the class.

Figure 6. Three designs of the TinkerLamp: the used model (left) and two new models.

The last examples come from the Lantern, a tool designed for orchestrating recitation sessions at the university level. Typically a first year course in physics is composed of two hours of lecture plus two hours of exercises per week. During these exercises, students work in small groups on a list of 8-10 exercises. When students are stuck, they raise their hands and one of the teaching assistants (TAs) comes when (s)he is available. This orchestration is fairly simple, yet it is far from being optimal. We observed (Alavi et al, 2009) that, while waiting for the TA, students spend 62% of their time visually chasing the TA. Other orchestration problems were observed such as unanswered questions (students give up) or the TA helping a team that has been waiting much less than another one. Alavi designed two tools to address these problems. The first one, named Lantern (Fig. 7 left) is a small device consisting of five LEDs installed on a stub-shape PCB and covered by a blurry plastic cylinder with one microprocessor to control the LEDs. By rotating the cover, students indicate which exercise they are working on: each colour corresponds to one exercise. The height of the colour bar indicates how much time has been spent on the current exercise. When a team wants to call the TA, they press the Lantern, and it starts blinking. The blinking rate increases slowly indicating the waiting time.

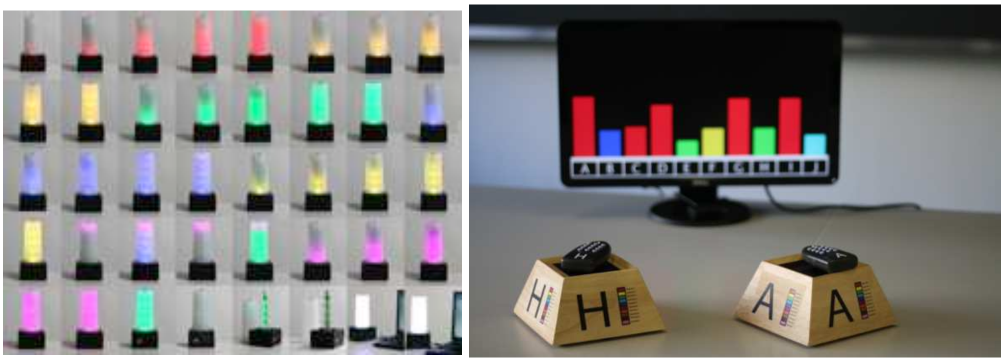


Figure 7. The Lantern device (left) and the Shelve environment (right)

The second tool, named Shelf (Fig. 7 right) uses exactly the same visual codes as Lantern, but students communicate with a remote controller and the status of all teams is displayed centrally on a single display. We provided both tools to two courses of physics. In both classes, students and TAs used Shelf for three weeks, after that they switched to use Lantern for four weeks. In total, Shelf has been used for around 12 hours and Lantern for 14 hours. The main result is that the estimated time wasted in chasing the TA was reduced from 62% in our early observations to 16% in the Shelve condition and to 6% in the Lantern condition. Students simply continue to work while waiting.

(16) These tools do not decide where the TA should go next. They simply provide TAs with some "awareness" of the teams' behaviour. They are not smart tools; they neither interpret activities nor predict the need to intervene, but they *simply make things visible that would otherwise remain invisible*: working time and waiting time. The decision remains in the TA's hands. Our *minimalism* does not only apply to the functionality of Lantern but also to its design. *We deliberately reduced the resolution of the display:* instead of displaying the precise exercise number and the exact waiting time, Lantern provides degraded information. The term "ambient" is used for displays that do not monopolize the visual attention of users. Minimalism is a key principle if we want to avoid that orchestration tools actually add more complexity to the teachers' tasks.

(17) The physical layout had an impact on the social processes. We observed that Shelf induced some competition between teams, while Lantern triggered collaboration between neighbouring teams: when Team could see that a neighbouring Team was moving to a next exercise (they changed colour), they would ask for hints. Lantern generated a social/spatial organisation of the classroom into spatial clusters of two to three teams. These two tools provide almost the same information but generate different social processes. Orchestration is physical: it is about mobility, gaze and distances between classroom actors.

(18) In CSCL, we rarely addressed the fact that teams peripherally perceive other teams. It was the case with Lantern but also with Tinker: students look over the shoulders of other students to see the warehouse being built by other teams. This does not change the kernel but the orchestration. Unlike desktops, tabletop environments induce indeed two interaction spheres: a one-meter radius sphere where students

manipulate objects on the table and a 5-meter radius sphere where students can see or hear what is done. "*Looking over the shoulder*" had a positive effect in the Lantern study but could have a negative effect in the Tinker classrooms (‘cheating’). Whether they are deliberate or accidental, desirable or not, "looking over the shoulders" and "over-hearing" are natural phenomena in classroom orchestration.

Final reflections

Forget the metaphor. Education has been inspired by metaphors from arts (orchestration, theater, script), biology (ecosystems) or military fields (targets, strategies). Metaphors are neither correct nor wrong: the mapping between the original meaning (Y) and the classroom (X) can be obvious or tricky. How can ‘orchestration’ in its musical sense be mapped to classroom management: who is the conductor, who plays the instruments, who is the audience, and the composer? The real issue is whether a metaphor is useful, i.e. if it helps understanding X by transferring our understanding of Y. Honestly, the ‘orchestration’ metaphor does not fulfill this criterion. *I prefer to drop the metaphoric claims that generate unproductive debates and to use ‘orchestration’ as a concept on its own*. This concept is useful because it refers to things that have been neglected in TEL design. We could use another word, less trendy, but it’s too late: because ‘orchestration’ conveys a certain flavor, it is becoming a flag for those who want TEL to have more impact on schools.

Not worth a theory. Orchestration is about the real time management of multi-layered activities in a highly constrained ecosystem. It is - at this point- a mere collection of pragmatic observations (rings), revealing neglected constraints. One could argue that this paper is more about the logistics of schools than about learning. Maybe, but these items are able to spoil the effects that best theories would predict. Orchestration is not yet a theory but a collection of opinions: non-refutable statements do not make a theory. I hope we can elaborate a theory that structures the different fragments that I listed: the whole range of activities, the list of constraints, the emergent principles of that I find too early to formalize (visibility, flexibility, minimalism), some orchestration-specific concepts (visual scan, over-hearing, overseeing). The great affordance of paper interfaces certainly constitutes a good avenue for deepening our understanding of orchestration.

Usability at the classroom level. A little step towards a theory is to define ‘orchestration’ as usability at the classroom level, what we called the third circle of usability (Dillenbourg et al, to appear). The first circle of usability is about the interaction between an individual and the system. The second circle is about how technologies shape team interactions. Let’s illustrate this with legibility. At Circle 1 of usability, HCI is concerned by how well the user perceives the display (readability, understanding of symbols, etc.). At Circle 2, CSCL/CSCW investigated if team members should or not perceive the same things (WYSIWIS: "what you see is what I see"). At Circle 3, a new concern is to analyze when team members look at the display of another team. For the Tinkerlamp, Circle 1 refers to the cognitive affordance of tangibles, Circle 2 to the emergence or roles in teams and at Circle 3 to the color of lamps or to the use of curriculum sheets. Another way to look at these circles is to see how they are constrained. At Circle 1, the design constraints are the individual cognitive, perceptive and sensori-motor skills, for instance cognitive load, audio perception, etc. At circle 2, the design constraints are for instance what Clark and Brennan called the 'costs of grounding'. The multiple constraints that shape the circle 3 have been listed here: discipline, time, curriculum, ….Metaphorically, orchestrations reflects a concern for usability considering the classroom as a user, in the same way Hutchins (1995) referred to a "cockpit that remember its speeds".

Modest computing. Lantern illustrates a certain design flavor that I call 'modest computing': the simplicity and transparency of the tool are favored over their power. They are not smart; some use a deliberately reduced display resolution, showing simple things, making visible things that would otherwise be invisible. Another example is the Reflect table, which shows conversation patterns in an ambient way. The technology push leads us to offer always more, but I am convinced that, from an orchestration viewpoint, less is more.

Improving education? I do not pretend that 'orchestration' will dramatically improve formal education. There are priority actions to do that: reducing the number of students per class, improving the quality of learning spaces, increasing the quality of teacher training, etc. My claim is that we have more chances that TEL is actually used in schools if the teachers' constraints are integrated into design. If the infrastructure is here while our tools are still not much used in classrooms, there must be something wrong in our designs. Participatory design is certainly the methodological answer. Orchestration is the conceptual answer.

Empowering teachers. An implicit message is that TEL environments should empower teachers in the difficult task of orchestration. Since TEL environments are becoming more open, teachers have a more intensive task of orchestrating complex scenarios. Empowering does not mean developing tools with thousands of functionalities but instead considering which real constraints shape their action, striving for minimalism. **Empowering teachers does not mean lecturing**: nothing requires a more subtle leadership than constructivist learning. In TEL, we have too often confused constructivism with 'teacherless' education. There is a single person who has the responsibility that other people learn, who has to share his passion, to broadcast his energy. He should neither be "a stage on the sage" nor "a guide on the side", as the slogan say, but rather "the guide on the stage" in this unique role of letting kids feel that (s)he expects them to learn.

Generalizability. Orchestration could be applied to cases where the classroom is a virtual classroom, the teacher is a friend or the learner himself, the integrated scenario is an on-line mesh environment. It's easy. However, if we generalize too much, orchestration will end up as a genuine concept such as adaptation or management. The salt of orchestration is in the classroom. Visit one, you will see.

References

Alavi, H. S., Kaplan , F. & Dillenbourg, P. (2009) Distributed Awareness for Class Orchestration. In U. Cress, V. Dimitrova & M. Specht (Eds). Proceedings of the 4th Europen Conference on Technology Enhanced Learning, pp. 211-225, EC-TEL 2009, Nice, France, Sept. 29th – Oct. 2nd. Springer, LNCS 5794

De Jong and van Jooligen (1998). Scientific Discovery Learning with Computer Simulations of Conceptual Domains. *Review of educational research*, 68, pp. 179-202.

Dillenbourg, P. & Fischer, F. (2007). Basics of Computer-Supported Collaborative Learning. *Zeitschrift für Berufs- und Wirtschaftspädagogik.* 21, pp. 111-130.

Dillenbourg, P., & Hong, F. (2008). The mechanics of CSCL macro scripts. *International Journal of Computer-Supported Collaborative Learning*. 3 (1), pp. 5-23

Hutchins, E. (1995). How a cockpit remembers its speeds. *Cognitive Science*, 19, 265-288.

Nussbaum, M. C. Alcoholado, A. Tagle, F. Gomez, F. Denardin, H. Susaeta, M. Villalta, K. Toyama (2010), One Mouse per Child: Interpersonal Computer for Personal Formative Assessment, Submitted

Roschelle, J. & Pea, R. (2002) A walk on the WILD side: How wireless handhelds may change computer-supported collaborative learning. *International Journal of Cognition and Technology*, 1(2) pp.145-168.

Zufferey, G., Jermann, P., Lucchi, A., and Dillenbourg, P. (2009) TinkerSheets: using paper forms to control and visualize tangible simulations. In *Proceedings of the 3rd international Conference on Tangible and Embedded interaction*(Cambridge, UK, Feb, 16 - 18, 2009). TEI '09. ACM, New York, NY, 377-384.

3. A response from M. Sharples

Mike Sharples, University of Nottingham, UK

The TEL research community has long neglected the dynamics of the real school classroom. Forty years ago TEL (or Computer Assisted Instruction as it was then) held out a promise of making life easier for teachers, while also enhancing the effectiveness of student learning.

"For so long teaching has been regarded as a human task that it is novel to suggest that a machine should take over the role of contact with the students, and leave a teacher to do the planning and preparation of the lesson. But it does seem to work, and in a world that is short of teachers there is every reason to develop it as far as possible." Dodd, Sime and Kay, 1968.

TEL has never delivered on this promise. Machines haven't successfully engaged in teaching students (with a few notable, but limited exceptions). Instead, the modern classroom has become a more complex and demanding place, with the teacher not only having to prepare lesson plans, accommodate formal curricula, and follow regulations on health, safety and discipline, but also understand and manage a variety of technologies such as interactive whiteboards, desktop and laptop computers. Into this volatile mix we're now proposing to add orchestration technology.

The new promise to teachers is similar to that of 1980s expert control systems: "You have to operate an increasingly complex dynamic system involving interacting people and technologies, so we'll add another layer of technology that will enhance learning while helping you to manage and interpret the system". It's the stock market dealing floor, or the nuclear power plant control room.

So, the modern classroom has a teacher managing interactions of students and technologies, (a). We add orchestration technology for "real time management of multiple activities and multiple constraints", (b). The intention is to develop "open scenarios for effective learning that can be managed on the fly by teachers" – a kind of fly-by-wire for the classroom. The reality is that teachers will not only have to learn and manage a new form of technology (for lesson design and real time classroom management), but will still have to interact directly with the students and their technologies, (c).

An example might help here, taken from an actual school lesson. The teacher and students were using an early version of our nQuire technology for inquiry science learning. The teacher was at the front of the class and each student had a netbook computer running nQuire. The teacher was managing a lesson where the students were sharing and analysing field data. All she could see were rows of laptop lids, with no knowledge of what the children had on their computer screens, and she was struggling to keep the children in order and working on the same task. So, one approach would be to add an orchestration system that allows the teacher to sit at a console where she could switch to any student's screen or take control of the students' computers, to orchestrate the lesson. But as well as communicating directly with the children, and enacting the lesson, she then has to view and manage their computers. A simpler solution would be to have a button she could push to 'freeze' all the computer screens and get the children's attention. An even simpler solution (which is what she used) would be to tell them to close the lids when she was talking – but they then had to power up the computers after each time she intervened.

The point of this anecdote is that, as Dillenbourg indicates, we have to confront the reality of the classroom and the demands on the teacher. We also need to understand the many things happening around the kernel, such as keeping the students focused on the activity. We need to find a way to deliver on the promise of enhancing learning while reducing (or not greatly increasing) the demands on the teacher. How can we do this?

Let's consider Dillenbourg's broader set of constraints.

Assessment must be part of orchestration. We need to build on imaginative forms of assessing collaborative and constructivist activities, such as peer and group assessment. Nussbaum's EDUINNOVA approach to small group mutual assessment is a good one, where the children first solve a problem individually, then have to reach a group consensus solution, which they then present to the class, with the individual and group outcomes being recorded and stored for assessment.

It's unrealistic to suggest that design for orchestration will reduce time. I have seen no evidence that adding the orchestration layer will save classroom time. Instead, I suggest we need to look for ways of increasing the time on task, by expanding the learning beyond the 50 minute lesson.

Discipline is important. Unless the teacher has some control over the class, then there's no chance of success. But there needs to be student self-discipline, imagination, improvisation, as well as teacher-imposed control.

Energy management is essential. Teachers don't have surplus energy to spend on designing scenarios and providing additional forms of feedback.

And, the classroom has to be compatible with activities that are performed in that classroom, but the learning doesn't have to be bounded by the classroom walls.

One way to deliver on the promise to teachers while designing for orchestration would be to simplify some component of the complex system: easier to use technology, simpler lesson plan, simplified task. We need to take Occam's Razor seriously, and not multiply entities beyond necessity. That means we should not impose a layer of orchestration technology unless it really can either simplify the task of classroom management without worsening the learning, or can substantially enhance the learning without imposing huge demands on the teacher.

Or we can remove the orchestration technology layer entirely, and just use 'orchestration' as a term to describe designs for real time management of innovative classroom activities. Then, as learning technologists we have to engage with the teacher's world of lesson planning and classroom management, for example offering advice on innovative lessons with interactive whiteboards, or showing how lesson plans can incorporate new devices such as smartphones as tools for innovative teaching, with all the difficulties this entails.

A third, more disruptive, approach is to share responsibility for orchestration between the teacher and the students. This is the one we have adopted for nQuire. In this form of orchestration, the teacher and all the students have similar computer toolkits designed to guide the students through a productive learning activity (for nQuire, an inquiry learning cycle), by means of an Activity Guide, rather like a 'dynamic lesson plan'. Normally, the teacher will select a pre-prepared Activity Guide and this can be modified in advance or on-the-fly by either the teacher or the students (for example, in nQuire the entire class or collaboration groups can alter the inquiry questions, decide on the method of investigation, select measures, change the visualisation). The Activity Guide is not a 'learning environment' with a few parameters to tune, but a guide to conducting open scenarios: recording findings, engaging in debate, creating shared outcomes. The students start the activity in the classroom, guided by the teacher, and then continue it beyond the 50 minute lesson, as homework or an outdoors activity. The responsibility for orchestrating their learning and enacting the activities lies with the students. Back in the classroom, the students share their findings in small groups and then present their conclusions to the class.

The advantage of this approach to orchestration is that the orchestration technology does not try to intercede between the teacher and the students, but instead acts as a guide for each person, teacher and student. The activities are not constrained to a 50 minute lesson, but can be continued as out of class work. The teacher is empowered to manage the lesson and to modify the Activity Guide. The drawbacks are that:

- The teacher and the students all need to know how to operate the orchestration technology – though in practice we have found the students manage this with little difficulty.
- The teacher needs to know that the students are continuing to manage their learning beyond the classroom – but that is true for any homework assignment.
- The results need to be coordinated back in the classroom. That is the tough one, and we have found that this coordination lesson does place additional demands on the teacher. If responsibility is given to student groups to integrate and present their findings, then the burden on the teacher is lowered, and she can concentrate on supporting the difficult groups and on drawing conclusions from the findings.

In conclusion, orchestration is a helpful word for TEL. We should not get too hung up on whether it refers to planning or real-time classroom management. As Dillenbourg says, we do need to consider seriously how technology-enhanced orchestration meets the reality of the modern classroom, and how to make the learning more effective not more burdensome.

4. A response from Y. Dimitriadis, L.Prieto & J. Ignacio

Yannis Dimitriadis, Luis Pablo Prieto and Juan Ignacio Asensio, GSIC/EMIC group, University of Valladolid, June 12, 2011

The orchestration metaphor has been recently one of the popular terms in the TEL domain (see Prieto et al., 2011a and Prieto et al., submitted). The metaphor appeared as a proposal by Dillenbourg, Fischer and others in various occasions, beginning in the mid-2000's (see, for example, Fischer and Dillenbourg, 2006; Dillenbourg, Järvelä and Fischer, 2009). Since then, the adopters of the metaphor have seen in it several interesting innovative elements. Among those motivating elements of the new orchestration metaphor we could mention:

- A generalization of the lifecycle or inquiry cycle in the use of ICT in education (as e.g. design, instantiation, enactment, evaluation)
- An analogy to the orchestration (choreography) metaphors in service-oriented architectures
- A movement towards a new blended version of teacher or student-centric procedures that promotes the need of teacher empowerment or more persistent and ambitious professional development programs
- A more pragmatic approach in pushing TEL into practice, taking into account and aiming to provide an answer to the contextual constraints that restrict a sustainable adoption of innovative TEL
- A new model, representation, or view regarding the integration of actors, tools and data artifacts at various social (from individual to community), tool-related (local or third party) or scenario-related (classroom, field, augmented reality, web-based, 3D, etc.) levels.

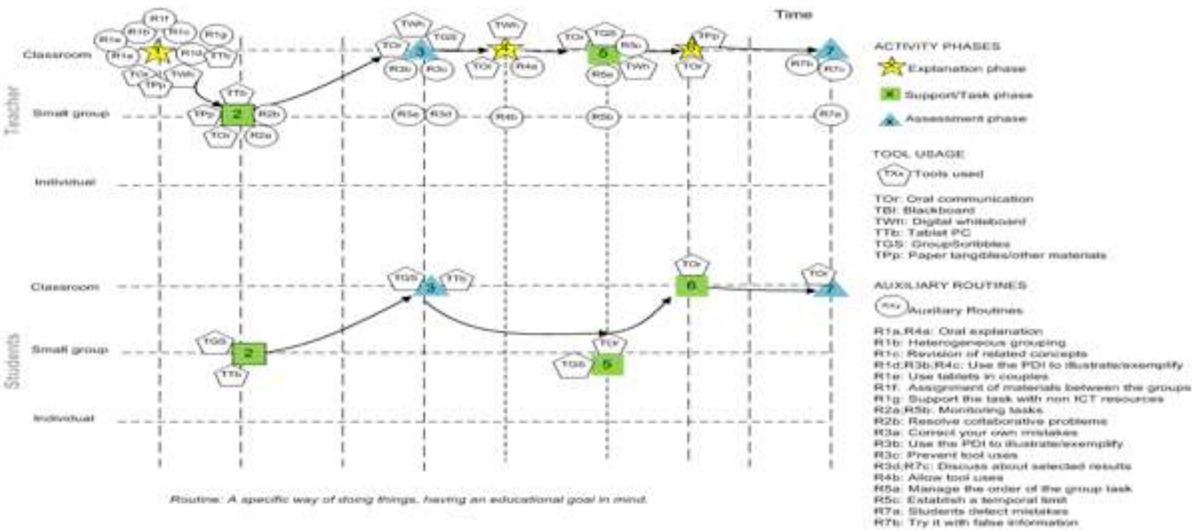
In his first position paper, Dillenbourg (2011, Jan. 5) uses the term "orchestration" inclusively, and mentions some of these interpretations. Later, in his stronger position paper, Dillenbourg (2011, Apr. 6) makes a more narrow interpretation of the initial use of the orchestration term, as "real-time management of multiple activities and multiple constraints" in a physical classroom. Besides that, in this second position paper Dillenbourg proposes a new representation or "model" based on a learning kernel surrounded by rings of "events" subject to several types of constraints.

Therefore, one might also consider the problem to solve as one of "optimization based on constraints" in which the teacher aims to orchestrate the classroom (instantiating, monitoring, reacting, assessing, etc.), and the researchers provide tools or design principles to support teachers and students. In conceptual terms, Dillenbourg proposes the use of an "orchestration layer", as Sharples (2011, May 30) mentions. The use of this "orchestration layer" reminds us of the equivalent middleware layers employed in Telematics or CSCW, regarding the separation of levels that allows for better communication, solutions at a given level, standardization, etc. but at the same time introduce additional complexity and overheads. Thus, Sharples suggests that introducing a new layer of "technology for orchestration" will only raise the demands on teachers and students, who have to learn to use (or circumvent) this new extraneous element. Sharples also advocates sharing the responsibility of orchestration between teachers and students, providing examples of the use of a new technology in classrooms.

From these discussions we can see a new trend rising, which we believe lies in the heart of the use of the "orchestration" metaphor: that of *how teachers* (or students) *appropriate and integrate in their practice the different technologies at their disposal* (either digital or paper-based, either generic or "for orchestration"). This relationship between orchestration and integration is related to what some authors called the "classroom as a complex technological ecosystem" (Luckin, 2008), and is exemplified by the title of the CSCL2011 workshop on orchestration ("How to integrate CSCL in classroom life: Orchestration").

We have studied this aspect of integrating new technologies in real classrooms (with all their contextual restrictions) and orchestrating lessons with them. More concretely, our two-year work with a primary school observing how a new, simple collaborative technology is integrated with other tools like pen and paper or digital whiteboards in usual curriculum lessons, has provided some insights about this problem. As it is mentioned in Prieto et al. (2011b), the uses and combinations of tools by teachers in the observed classrooms were highly *"routinized",* and precisely using this kind of small-scale pedagogical patterns in professional development efforts has proved useful in our attempts to foster reflective design and enactment of collaborative learning activities. In fact, similar results have been gathered from an independent project at SRI International (see Prieto et al, 2011c), where small, actionable pedagogical patterns have been found a good way of fostering the use of new technologies (e.g. clickers or Group Scribbles) to enhance science learning in middle schools. *This line of work thus suggests that, in order to obtain better-orchestrated classrooms that make use innovative TEL tools, not only the technologies have to be provided, but also best practices, principles and advice (in our case, exemplified by design and enactment patterns) on how those tools can be integrated with the existing "classroom ecosystem", and within the complex set of constraints that teachers have to face (time limits, curriculum, disciplinary concerns, etc.).* Going back to one of the examples provided by Dillenbourg, the Tinkerlamp, we could imagine it being introduced in many logistics schools. We suggest that providing the school with the technology could be complemented with providing teachers with easily-digestible advice on ways of using it (along with other existing technologies) that have proved successful, and which may not be obvious to teachers approaching the new technology: "copying the layout information to the whiteboard to discuss it with the larger group", "taking the design to a real warehouse and comparing them", "using POKs to elicit students reasoning before running the simulation", etc.

Apart from the aforementioned problem of integration of new technologies in real classroom settings and real classroom practice, there is another aspect in Dillenbourg's proposal which we believe is worth highlighting: the value of orchestration (and the related artifacts such as the "kernel and rings" representation or the "constraints" framework) as conceptual tools for us, researchers, to understand and communicate with each other about current classroom practice. These frameworks and representations can also help researchers in proposing new solutions for real classrooms, be them either technological or conceptual tools. In this same light could be seen the *“Five+Three aspects” conceptual framework* for orchestration mentioned in Prieto et al. (2011, submitted), or the *routine-based representation of classroom practices* that appears in Prieto et al. (2011a), which is also reproduced below:



<u>Figure 1</u>. Visual representation of an activity enactment observed in a primary school classroom.

All in all, the different interpretations of the orchestration metaphor and the proposed models could be subject of long discussions among researchers, especially since they come from different origins (see e.g. the different existing conceptualizations for scripts, learning designs, workflows, patterns, etc.), or when technology evolves through time so fast, independently of the general conceptualizations that may become obsolete. *Our appreciation is that the proposed “model” (kernel, rings, constraints) is especially interesting,* although it may suffer the same problems as the general metaphor of orchestration. However, some of its main ideas can be proved to be very useful as a general conceptualization framework and as means to provide specific solutions.

Since commenting on all the aspects of Dillenbourg’s proposal would far exceed the scope of this short position paper, we will finish by providing a few parting remarks summarizing our own take on orchestration, based on the prior work of GSIC/EMIC (Dimitriadis, 2011) and the review of the existing literature (Prieto et al., 2011a and Prieto et al., submitted)

- **Orchestration in the classroom vs. other contexts**: Orchestration in physical classrooms is very significant and affects indeed a large amount of students and teachers. However, as Sharples mentions, learning activities do not only take place within the walls of a classroom or with local tools. Within the concept of “ubiquitous learning”, TEL may involve augmented reality or “ambient technology” elements (such as many of the exciting artifacts proposed and developed by Dillenbourg’s team), virtual web-based tools, virtual 3D worlds, field trip or home-based mobile-learning devices, etc.). Thus, there is a need to orchestrate *beyond* the activities of the physical classroom and provide for efficient solutions for a wider range of scenarios, taking into account transitions, mirroring phenomena, or overlapping between different spaces. This wider view is intrinsically more complex, but at least it should be taken into account.

- **Importance of design principles and other research artifacts**: Dillenbourg argues that studies in orchestration could eventually derive in a set of design principles that could be used especially by practitioners. In his paper he offers many examples of design interventions together with attempts to provide an abstraction of these design “ideas or principles”. This bottom-up study of his own research and the existing literature (e.g. from Nussbaum’s work) is very useful and it could form the basis for a more coherent framework. We have performed similar research in the design field for the last few years and we have proposed several “mediating artifacts” that may be useful for practitioners. Some of them correspond to “design patterns”, or “enactment routines”, which we have briefly presented above.
- **Design – in or out of orchestration?** The term “design for orchestration” implicitly means that design is not part of the orchestration itself. We do believe that design and other forms of lesson planning is intrinsically interleaved with the “real-time management” (i.e. instantiation and enactment), even if teachers (as opposed to, e.g. instructional designers in an open university) sometimes do not have enough time to perform explicitly a formal design. Thus, more attention should be paid to the role of design, even if orchestration is used in a more restrictive sense, while there is a need for a deeper analysis of the place of design and real-time management within the complete lifecycle.
- **Sustainability and “modest computing”**: Monitoring, assessment, mirroring, scaffolding, etc. are illustrated effectively by Dillenbourg in several examples and show the importance of contingent teaching (Beatty et al., 2006) and the eventual role of technology in scenarios of collaborative and/or inquiry learning. The use of different devices built ad-hoc is very innovative and useful, although one may question sustainability of complex ad-hoc technologies. We would also argue for the use of “modest” technology and especially for the one based on paper (see the paper element that allows for configuration in one of Dillenbourg’s examples). We also support the use of paper-based elements, as they are already integrated in most teachers’ routines, and have proven to be very useful in our professional development workshops that take advantage of the aforementioned routines.

Overall, we believe that these discussions on orchestration are very relevant to the future of TEL, and its impact on a wider scale. In fact, we would like to highlight the importance of *finding ways of promoting the integration and appropriation of innovative research-based tools* (with patterns and routines being only some of the possible options), as a way of attaining better-orchestrated classrooms. Many of the researchers involved in this discussion have showed that they understand and share this view, which might be a worthy message to spread among the rest of the TEL community, even if we do not manage to agree on what exactly is orchestration, and what isn’t.

References

Beatty, I., Gerace, W., Leonard, W., & Dufresne, R. (2006). Designing effective questions for classroom response system teaching. *American Journal of Physics, 74*(1), 31-39.

Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research in Computer-Supported Collaborative Learning: from design to orchestration. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, and S. Barnes, editors, *Technology-Enhanced Learning*. Springer.

Dillenbourg, P. (2011, Jan. 15) "Orchestration: the relationship between planning, design and adaptation", internal STELLAR paper.

Dillenbourg, P. (2011, Apr. 6) "Design for Orchestration", discussion paper.

Dimitriadis, Y. (2011) Supporting teachers in orchestrating CSCL classrooms. In A. Jimoyannis, editor, Research on e-learning and ICT in education: Technological, pedagogical and instructional issues. Springer.

Fischer, F., & Dillenbourg, P. (2006). Challenges of orchestrating computer-supported collaborative learning. *Paper Presented at the 87Th Annual Meeting of the American Educational Research Association (AERA)*

Luckin, R. (2008). The learner centric ecology of resources: A framework for using technology to scaffold learning. *Computers & Education, 50(2)*, 449-462.

Prieto, L. P., Dimitriadis, Y., Villagrá-Sobrino, S., Jorrín-Abellán, I. M., & Martínez-Monés, A. (2011a). Orchestrating CSCL in primary classrooms: One vision of orchestration and the role of routines. *"How to integrate CSCL in classroom life: Orchestration" workshop, International Conference on Computer-Supported Collaborative Learning (CSCL 2011)*.

Prieto, L. P., Villagrá-Sobrino, S., Jorrín-Abellán, I. M., Martínez-Monés, A., & Dimitriadis, Y. (2011b). Recurrent routines: Analyzing and supporting orchestration in technology-enhanced primary classrooms. *Computers & Education, 57*(1), 1214-1227.

Prieto, L.P., Villagrá-Sobrino, S. Dimitriadis, Y., Schank, P., Penuel, W. and DeBarger A.H. (2011c). Mind the gaps: Using patterns to change everyday classroom practice towards contingent CSCL teaching. *In Proceedings of the 9th international conference on Computer-SupportedCollaborative Learning (CSCL 2011)*.

Prieto, L. P., Abdulwahed, M., Holenko-Dlab, M., Balid, W., & Gutiérrez, I. (2011, submitted). Orchestrating Technology-Enhanced Learning: Challenges in Literature, in Practice and Beyond. *Paper submitte for publication, under review*.

Sharples, M., (2011, May 30). "Response to Dillenbourg" discussion paper.

5. A response from J. Roschelle

Jeremy Roschelle, SRI, USA.

I see "orchestration" as a beacon drawing designers to pay attention to a new level of concerns beyond the "active ingredient" of our innovations, but as Dillenbourg points out, the exact meaning of "orchestration" is still fluid.

Let me suggest a few of the positive things that a focus on orchestration could achieve:

- Robustness. We acknowledge that there are innovative ways to teach and learn into a variable environment. This additional layer of design may keep unplanned variation from turning into a fatal mutation.
- Efficiency. We acknowledge that innovative ways to teach and learn may be initially less efficient that existing ways to teach, especially when teachers focus on how many concepts they can "cover" per unit time. This additional layer of design may gain back some of the time consumed by using innovate resources.
- Adoptability. We acknowledge that teaching is already difficult and many teachers are reluctant to adopt something new and unfamiliar if it seems disorganized, harder, and unfamiliar. This additional layer of design may make an innovation seem more coherent, attractive, and helpful to the teacher.
- Adaptability. We acknowledge that teaching is often contingent on what happens in real time in the classroom and that excellent teachers often adapt their teaching plans to the unfolding action. This additional layer of design may enable teachers who are implementing an innovation to take advantage of "teachable moments."

Based on my experiences in trying to get technologies to scale, these four properties are quite essential to scaling up an innovative core idea. In addition, I agree with Dillenbourg's design aesthetic, which tends towards ambient indicators. Given the real-time pressures of teaching, additional tools should be simple, easy to interpret, and at the periphery of perception. In my view, simpler technologies that enable teaching and learning to emerge in complex ways are to be much preferred over complex technologies that constrain teaching and learning to simple choices.

As food for further thought, I suggest that we consider what the time, space, and kinds of materials that orchestration should span.

With regard to time, I believe it is artificial to separate real-time performance in the classroom from either planning or reflection. If we have real-time capture of which students need help, why not occasionally reflect over the help seeking patterns in the classroom, and design better teaching plans around the patterns? Likewise, why not make real-time orchestration tools permeable to planning? Perhaps a teacher would like to collect resources which may be useful during the class ahead of time, and organize them "just in case" they might be useful as the classroom session plays out.

With regard to space, I think that the layout of space in the classroom critically determines what kinds of orchestration are possible. What kinds of groupings of students does the classroom space permit? Where can display surfaces be located? How easy is it to move about?

Finally, with regard to materials, I am not sure that the only appropriate materials for designs for orchestration are computational in nature. We've sometimes used hats to give student roles; besides being fun, the hat serves as an easy visual cue for the particular role (e.g. "red hat" = critic). We've often designed paper workbooks to scaffold and organize classroom activity and there are many circumstances in which paper is still preferable to the teacher and students over computation materials. It is generally easier, for example, to sketch on paper. Other orchestration techniques can use no materials at all. For example, Stephen Hegedus has effectively used "counting off" (where each students says a number in the sequence 1, 2, 3, 1, 2, 3, 1, 2, 3….) to ask students to each explore a different parameter in a mathematical equation. For example, students can be asked to graph y=1/3 x + C, where C is their count off number. The resulting family of equations reveals patterns that are harder to see with only one example of graphing this line.

To wrap up, I heartily endorse an effort to thoughtfully address robustness, efficiency, adoptability and adaptibility so that the kernel of our CSCL innovations might scale to meaningful use across classrooms and where variation among settings, teachers and students might not just been see as "noise" that we must control but also as latent energy that we could harvest. Indeed, I recall Walter Stroup once making this point profoundly to me. I can't remember his exact words, so I will paraphrase in my own: Most designers aim for the mean on an imagined bell curve of classrooms and thus try to normalize diversity; instead could we harness the cognitive, social and emotional diversity of classrooms for more engaged, meaningful learning?

6. A response from M. Nussbaum & A. Diaz

Classroom Logistics: Integrating Digital and Non-digital Resources

Miguel Nussbaum & Anita Diaz, Pontificia Universidad Católica de Chile

We agree with Dillenbourgs' relation between Orchestration and Classroom Logistics in his article Design for Orchestration and want to analyze in a deeper degree the relation between classroom logistics and learning.

You remember using Word 2003. You felt confident, and found it comfortable to use. But then the day arrived when you had to upgrade to Word 2007. For most of us, it was an unproductive week that we remember with distaste. Put yourself in the shoes of a teacher, bearing in mind that it is very likely that they don´t possess the same technological experience that you do. Now imagine that they have had a couple of hours training in a specific educational program and it is now expected, following this training, that they will use this software in front of the entire class. Why should that teacher feel any more comfortable and confident than you did during those first moments with Word 2007?

The logistics of schools have been neglected. We presume that knowing how to use a program is sufficient. What we have to do is resolve the process by which we integrate conventional resources already familiar to teachers with digital technology. In order to achieve this, it is not enough to merely plan a class integrating different resources, but instead it is necessary to specify the precise actions that the teacher must undergo in order to apply the proposed strategies for the integration of digital and non-digital educational tools to perform the work with the students. The teacher needs to be guided explicitly in this process, defining what the classroom work should be, and leaving what they finally do up to them. It is easier to skip over a given content than to think about what is missing.

Everything should be specified and nothing left to chance. It's like a computer program with unspecified paths; when it reaches these paths we don't know what will happen. The teacher can use the specified script to detail if he wishes; unlike a computer program he can decide to follow, modify or skip the proposed steps. But, if the proposed process is not in place when it is required, the teacher could abort or do something contrary to the whole philosophy.

The adoption process will be successful so far as the teacher feels that it is better to do the class in the proposed way than to follow their old teaching habits. Our aim is for the teacher to feel that "it works in my classroom". In that moment they make it their own and it then belongs to them.

A proposal

Our logistics have to be defined for everybody. There are only a few heroes and they can manage by themselves. Our proposal is to empower the teacher in all areas of the class, from the beginning until the end, by providing them with different strategies to maintain the students' interest throughout a range of challenges aimed at the achievement of proposed pedagogic objectives. Our specification is determined by three elements, which are specified in detail as follows.

1. Context of the class:
   - Grade or course targeted in the activity
   - Area of the curriculum
   - Name of the unit.
   - Time dedicated to the class
   - Week in which the material will be treated
   - Number of sessions in which the material will be treated
   - Level of difficulty
   - Cognitive Process (Recall, Understand, Apply, Analyze, Evaluate, Create) (Anderson et al., 2001)
   - Previous learning required for the development of the class.
2. Aim of the class:
   - Specific objective of the unit
   - Objective of the class
   - Skills and attitudes to be developed in the students
3. Specification of the lecture:
   - Class-time moment (Mehan, 1979):
     - Opening phase
     - Instructional phase
     - Closing phase
   - Pedagogical Process (Guthery, 2007):
     - Deductive process
     - Inductive process
   - Class Activities:
     - General indications about the organization of students.
     - Specific questions to be asked to the students and their expected answers
     - Description of the planned activities, referring to the specific actions of the teacher, and explicitly stating what is expected of the students.
     - Guidance in the use of the integrated resources for each activity
     - Formative assessment guidelines (Black et al., 1998)
     - Time assigned to each activity.
   - Resources
     - Paper guides
     - Interactive guides on the computer
     - Presentations with/without audiovisual support
     - Individual/group work with/without technological support
     - Participatory work involving the whole class.
     - Complementary activities/homework.
     - Online resources

Conclusion

Warschauer indicates that the introduction of information and communication technologies in the schools he observed served to amplify existing forms of inequality (Warschauer & Knobel, 2004). The aim of our proposal is to transform the role of technology in the classroom to empower the teacher and transform the learning process. An adequate orchestration permits to guide the teacher in the work to be performed in the classroom, which allows shifting from an instructor-centered arrangement in which the teacher radiates knowledge before a passive class of students to one where the students actively participate with a teacher acting as a mediator. Our proposal, which is currently used in Chile in more than 50 schools, and soon to be used in Uruguay and Colombia, can be seen as a bridge to embracing the learning process as an interactive and collaborative experience.

Bibliography

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruickshank, K. A., Mayer, R. E., Pintrich, P. R., et al. (2001). A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives (Abridged ed.). New York: Longman.

Black, P.; Wiliam, D., Assessment and Classroom Learning, Assessment in Education: Principles, Policy & Practice, March 1998, Vol. 5 Issue 1, pp 7-73

Guthery, F.S., (2007), Deductive and Inductive Methods of Accumulating Reliable Knowledge in Wildlife Science, The Journal of Wildlife Management , 71(1), 222-225

Mehan, H. (1979). Learning lesson: Social Organization in the Classroom. Cambridge, M.A.: Harvard University Press.

Warschauer, M., Knobel M., (2004), Technology and Equity in Schooling: Deconstructing the Digital Divide, Educational Policy September 2004 vol. 18 no. 4 562-588

7. A Response from C.-K. Looi

Orchestration in the Context of a Networked Classroom

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Orchestration

From a social constructivist perspective, in real time Computer-Supported Collaborative Learning (CSCL) classrooms, the teacher's role has often been associated with a "conductor" orchestrating a range of activities that lead to knowledge creation rather than a knowledge provider transmitting information to students (Beauchamp, Kennewell, Tanner, & Jones, 2010; Dillenbourg, Järvelä, & Fischer, 2009). According to Dillenbourg (2011), "orchestration refers to the real time management of multiple activities and multiple constraints", and "orchestration expands instructional design". The author calls for design for orchestration as a means of traction for impacting educational practices.

Dillenbourg uses a neutral word "kernel" to refer to the core instructional design (e.g., sequence, the lesson plan, the scenario, the script), and orchestration is concerned with regulating various activities and constraints around the "kernel". Indeed, CSCL is embedded in social context which includes complex factors. Different "kernel" designs require different pedagogies and different affordances of collaborative technologies, hence contributing to different activities and constraints. This, in turn, requires different ways of orchestration, including improvised orchestration of activities that expands the "kernel" design.

In response to Dillenbourg's design for orchestration, we share our experiences with GroupScribbles (GS) classrooms in Singapore. We first present our "kernel" design, pedagogy and affordances of this collaborative technology followed by the design for orchestration of the activities and constraints that expands the "kernel" design.

"Kernel" design

Our "kernel" design is concerned with progressive inquiry supported by GS. The progressive inquiry approach is proposed by Hakkarainen (2003) for young learners' knowledge creation in a CSCL environment. Five principles are included in the "kernel" design, aiming at elucidating the processes and dynamics of collaborative inquiry and guiding the progressive inquiry pedagogical approach. The five principles are: (a) working on authentic problems, (b) encouraging diverse ideas, (c) making progressive inquiry, (d) providing collaborative opportunities, and (e) doing formative assessment.

Affordances of Collaborative Technology - GroupScribbles

A typical GS classroom is equipped with an Interactive Whiteboard (IWB), and each student in the classroom has a Tablet PC with the GS client software installed (Fig. 1). GS allows students to create, publish and edit lightweight multimodal expressions (text, drawing, and painting) for group activities. The GS user interface presents each student with a two-paned window. The lower pane is an individual work area, or a private board, with a virtual pad of fresh scribble sheets of different sizes. The upper pane is a group work area, or a group board. The student can draw or type on the scribble and can drag and drop it into different screen arrangements on the group board in the upper pane. Other participants' screens are updated to reflect changes on the group board. Teachers can access the group postings on the public board.

Design for orchestration in GS-supported progressive inquiry classrooms

Making use of the GS affordances, the teacher's orchestration of the inquiry class can be designed holistically at three levels: individual, group and whole class activities (see Figure 2). The teacher can orchestrate the multiple level activities interchangeably according to the pedagogical goals enabled by GS. As GS can provide the teacher with a bird's-eye view of the participation and performance of individual students and groups, it helps the teacher monitor the ongoing process and performance of the students more effectively. Table 1 shows the design for orchestration at multiple-levels in a mathematics lesson on fractions in a Primary 5 class (Looi & Chen, 2010).

With GS, the teacher can orchestrate the activity from one level to another anytime to address different pedagogical needs such as: to ask the students to participate more actively in the discussion if the teacher finds fewer postings on the group board; to ask students to perform on tasks requiring multi-modal representation use if the teacher identifies only one form of modality is used; to ask groups to do more intra- or inter group embedded assessment if the teacher hardly finds any postings in proximity of postings; to praise the groups if the teacher finds the postings are multi-modal, adjacent and adequate so that the groups can perform better, and other groups can learn from them; and to comment on a group's work in close physicality with some of the other groups possibly eavesdropping onto the teacher's conversation with the first group and thereby learning something.

We observed one Primary 5 mathematics lesson on division and fractions, and coded one scenario (from 00:09:30 – 00:23:50) of how the teacher orchestrated student progressive inquiry into ways of dividing two pizzas among three children at three activity levels supported by GS (see Fig.9).

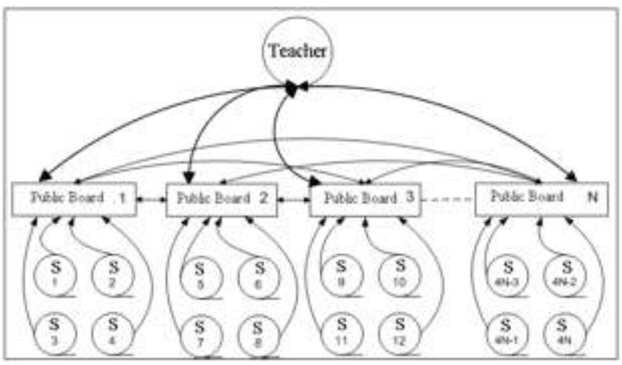

Figure 1. GS classroom seating arrangement

Figure 2. Model for social interaction in a GS classroom

Figure 3. Monitoring individual participation

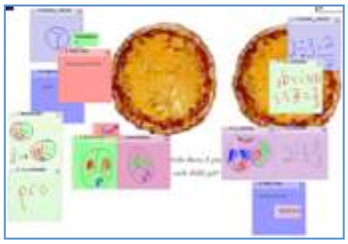

Figure 4. Monitoring active participation

Figure 5. Space with lack of multi-modal representations

Figure 6. Space with multi-modal representations

Figure 7. With intra- and inter- group embedded assessment

Figure 8. Group work projected on the white board for class discussion

Fig. 8 shows that the teacher orchestrated the class scenario with real-time improvisation at different activity levels for different purposes to make the progressive inquiry run smoothly and productively. These activities are emergent and can be described as "rings" which expand the "kernel" design. Our example of shared group and classes spaces in GS provides a platform for the teacher to have awareness of individual, group and class work and to be able to improvise in real-time to manage intra- and inter-group interactions.

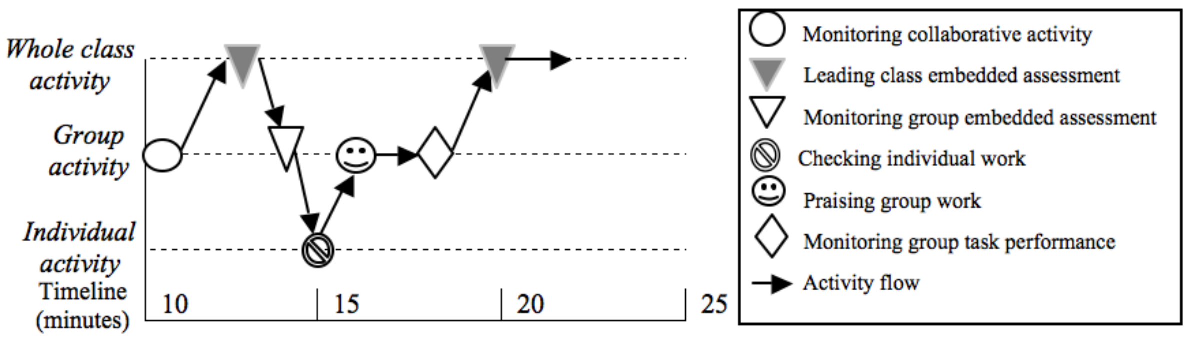

Figure 9. Class activity patterns orchestrated by the teacher

Our approach has been to design simple and minimalistic technology support for empowering teacher orchestration, rather than complex technology support for supporting perhaps less flexible teacher orchestration moves. We have shared the work of a teacher who successfully orchestrated the class activity. However, out of the hundred over GS lessons we have supported in Singapore classrooms, there are also some GS lessons that were not like this and that did not "work well" – the teacher succumbed to some constraints like lack of curriculum time to complete the lesson, or inability to seize on teaching moments at the individual, group or class level. The same design of the technology and the learning activities are there, but different teachers in different subject areas have different degrees of success in leveraging the technology to orchestrate the class well. While an important key is in the GS activity design, teachers will ultimately orchestrate in varied ways and styles based on their technological, pedagogical, and content knowledge, and their different beliefs. A networked classroom can be inadequately orchestrated if teachers have no good understanding and capability to integrate the affordances of technologies, and to take into account the ability of students and the characteristics of different disciplinary knowledge. The design of a learning environment, unlike traditional instructional planning, involves more unpredictable elements, and orchestration itself is unplannable. Orchestration depends on what is happening in real time classroom and how the teacher handles the dynamic environment. Therein lies the need to empower teachers to practice and develop good orchestration skills.

References

Beauchamp, G., Kennewell, S., Tanner, H., & Jones, S. (2010). Interactive whiteboards and all that jazz: the contribution of musical metaphors to the analysis of classroom activity with interactive technologies. *Technology, Pedagogy and Education, 19*(2), 143 - 157.

Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning. In N. Balacheff (Ed.), *Technology-enhanced learning principles and products*. Dordrecht ; London: Springer.

Dillenbourg (2011, April). *Design for Orchestration*. Position paper.

Hakkarainen, K. (2003). Progressive Inquiry in a computer-supported biology class. *Journal of Research in Science Teaching, 40*(10), 1072-1088.

Looi, C. K. & Chen, W. L. (2010), Community-based individual knowledge construction in the classroom: A process-oriented account, *Journal of Computer Assisted Learning*, 26 (3), 202-213.

Table 1 Design for orchestration at three-levels

Activity level	Orchestration	Purpose	Example
Individual level	GS postings are anonymous to the students. However, the teacher can activate the function of "show student names" on GS. By viewing the student names on the group board, the teacher can get a gallery view of individual student contributions.	Monitor individual participation	Fig. 3
Group level	Based on the number of contributions of each group work and a quick sense of some of the contributions, the teacher can get an overview of which group has actively participated in the discussion, and which groups have not done so.	Monitor group participation	Fig. 4
	Based on the contributions of each group work, the teacher can identify which group members have used multi-modal representations required by inquiry tasks, and which group members have not done so.	Monitor group task performance	Fig. 5 Fig. 6
	Based on the proximity of the postings on each group board, the teacher can understand whether there are intra- and inter-group comments.	Monitor intra- and inter- group embedded assessment and social interactions	Fig. 7
Whole class level	The teacher can project group work from the group board onto the white board, and ask the class key questions raised from the group board	Lead whole class embedded assessment and arouse students' awareness of key points in progressive inquiry	Fig. 8

8. A response from P. Tchounikine

Orchestrating TEL settings: scripting and conducting

Pierre Tchounikine, LIG, Université de Grenoble 1, France

Introduction

The use of the orchestration metaphor in Technology Enhanced Learning (TEL) as "what the person in the middle of the orchestra (transposition: classroom; on-line setting) is doing with the help of the baton and gestures (transposition: with instructions, hints or by tuning the computer-based system's parameters)" seems to be based on confusing:

- Orchestrating, which is about writing music for an orchestra, i.e., deciding how some music should be played by a set of instruments.
- Conducting, which is about directing performance, i.e., directing the way the musicians perform the orchestration.

Dillenbourg suggests dropping the metaphor and proposes a definition: "Orchestration is about real-time management of multi-layered activities in a highly constrained ecosystem" [1]. This definition makes clearer what the issue is. This issue is not new. However, re-installing orchestration as a key issue of the field and giving it a definition that is in-line with current uses of technology in education is of interest. In particular, what "multi-layered activities" or "ecosystem" refers to is significantly different from what was considered in, for instance, ITSs. Dillenbourg highlights the fact that settings now involve different modes (individual and collective, in class and on-line, etc.). I would add the fact that ICT has changed the context in different ways from which the fact that actors (teachers, students) come with their technology and their technological skills and habits, and are not dependent (and do not want to be dependent) on Computer Scientists anymore. Actors tend to use whatever tool they will contextually find available and convenient: the applications running on their smart phones, software they have installed on their laptop, available Web-services (etc.), which may vary from actor to actor and from session to session. Within such an approach, in some sense, software is a contextual construction. Moreover, although in some cases the setting involves specifically designed software, users' usages and expectations are influenced by this general evolution.

Orchestration as introduced by Dillenbourg is mainly about empowering human teachers. The orchestration concept is not limited to the context of classrooms and orchestration by teachers but, indeed, the way technology is used in classrooms and the specificity of this context gives importance to this issue.

Orchestration technology and orchestrable technology

In order to make clearer what designing for orchestration means, I propose to disentangle orchestration technology and orchestrable technology:

- Orchestration technology is technology that achieves or supports the activity of orchestrating.
- Orchestrable technology is technology which use can be decided or adapted (before the session and/or at run-time) by the actors in charge of the orchestration (the teacher, a system) while orchestrating the setting, in the same way that other parameters of the setting (the timing, the groups, the task, the physical space, the pedagogical objectives, etc.) may be adapted.

Orchestration technology may correspond to different realities such as:

- Technology that manages the setting (as ITSs attempted).
- Technology that provides teachers with some support for managing the setting, for instance:
    - Technology that renders some dimensions of the setting salient (dimensions of interest for orchestration). An example is tangible interfaces rendering learners' workflow salient [1].
    - Technology that provides teachers with monitoring or intervention means.

Orchestrable technology may correspond to different realities such as:

- Flexible technology, i.e., technology reifying in some way or another some given pedagogical intentions (e.g., a workflow structuring learners' activity) while allowing some tuning and run-time adaptation by teachers (or the system itself) or learners.
- Creating-affordance technology, i.e., technology which usage is likely to create pedagogically-rich events. Here, there is an explicit decision not to design and consider technology according to a single precise targeted usage. Rather, the artifact is meant to allow different usages, and give the actor in charge of the orchestration some latitude with respect to how students will be prompted or allowed to use it.

Scripting and conducting

In classrooms or in on-line settings, managing unexpected events or taking opportunities requires real-time [1]. However, real-time management does not mean there is no pre-session management. Here, one might come back to the music metaphor and the disentanglement of *orchestrating* and *conducting* as processes[1]. Orchestrating may be seen as a process within which an orchestrator analyzes the way different means (registers, instruments, dynamics, etc.) may be used in order to obtain a targeted enactment (the musicians' performance) and makes design decisions with respect to this objective.

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[1] As I am a not a musician, the way I use this metaphor may not be more pertinent than that of others. Therefore, readers should stick to the view introduced here, although some others may exist and be more coherent with the musical context. This is in opposition with the interest of metaphors but, anyway, metaphors are not good for science.

Conducting may be seen as a process within which a conductor, using the orchestration as a resource, analyzes the setting enactment (what happens) and uses different means to influence the setting enactment and, in particular, what performers do. Here, orchestration is a pre-session process and conducting a run-time process.

As we already use orchestration as a more general concept, I will call “scripting” what is called “orchestrating” here before.

Within this perspective, orchestration in TEL may be analyzed by disentangling *scripting* and *conducting*:

- *Scripting* is about envisaging how a set of means should be used in order to address pedagogical objectives. It is an analysis, design (from scratch or by adaption) and taking-decisions task, which result is a resource for action. As an example, scripting a CSCL setting may include:
    - Analyzing the way means such as tasks and sub-tasks definitions, tasks distribution, roles, scheduling, data-flow, technological framework, offered scaffolding or physical space may be used to obtain some targeted students’ activity.
    - Making design decisions.
    - Attempting to anticipate some real-time issues (as much as possible) by introducing some flexibility [2]: how the teacher and/or software may react (or be adapted) in response to the absence of a member of the group, a timing issue, a dispute, a technological failure, etc.
    - Representing decisions in a way that enables their implementation by students, teachers and/or platforms. The output is what is usually called “the CSCL script”.
- *Conducting* is about contextually communicating directions to performers and adapting the setting components or their articulation. Here, the main performers are the students (there may be other actors such as tutors) and the setting is defined by the technology, the physical space, the timing, etc. As an example, conducting a CSCL setting may include:
    - Analyzing the script unfolding and the students’ individual and collective activity.
    - Providing students with directions, support, hints (…).
    - Tuning the technology, using the system’s flexibility, changing the physical space, etc.

Run-time scripting

Scripting and conducting as introduced here do not correspond to separate period of times, but to analytic distinctions of the activities involved in orchestration. In particular, if conducting occurs during the session, scripting takes place before the learning session and during the learning session (with different modalities). For instance, an orchestrated CSCL session may be viewed (from the teacher’s perspective) as:

1. Consideration of targeted pedagogical objectives.
2. *Primo-scripting* (definition of the initial script and associated technology).

3. Conduct of the script, which consists in a mesh of:
   - Analyzing the enactment (the performance).
   - Providing students with support and hints, tuning some parameters, etc.
   - When needed, *runtime-scripting*, i.e., reconsidering objectives and/or means.

Deciding to change the task, roles, schedule, technology, space (etc.) in a way that had not been envisaged as primo-script's flexibility (which often happens) is not conducting the script, it is dynamically adapting the script. This is the same activity as scripting (envisaging how available means should be used in order to address current objectives) but it is achieved at run-time, conducted in relation to the current script, and in the light of run-time input (the current-script's unfolding): it is *run-time scripting*. Run-time scripting may be minimal (e.g., locally over-ruling the script) or lead to important modifications: change the way some means such as decomposition of work or distribution of roles where used; abandon some technology or use some additional one; change the objectives (abandon the targeted objective for another more in-line with the setting unfolding in order for the session not to be a total failure; build on an unattended episode; consider new dimensions such as preserving or developing social relationships; etc.); change the didactic envelope (e.g., add a post-activity that will build on what effectively happened); etc.

5. Scripting and conducting CSCL settings

As a way to see how these different notions relate one to another, we may take as an example CSCL scripts and the general model of CSCL scripts operationalization summarized in Figure 1.

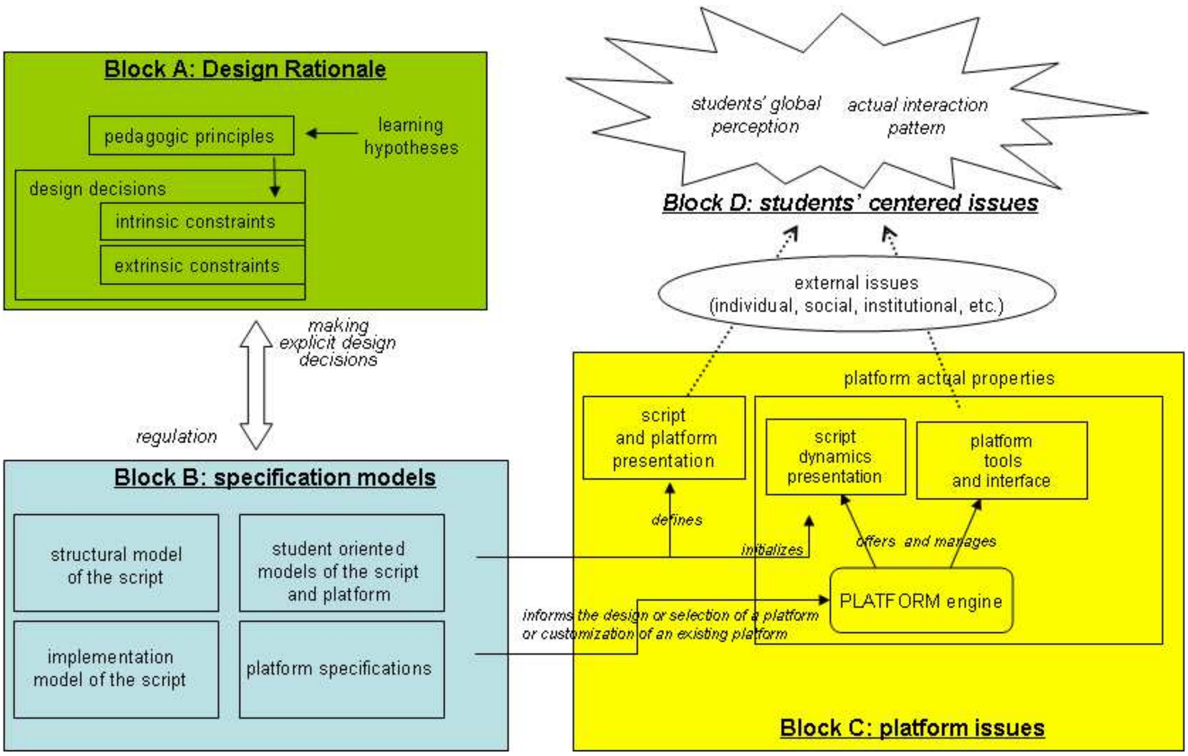

Figure 1. Operationalizing CSCL scripts [3]

Primo-scripting may include (items are not in strict order):

- Given the pedagogical objectives and the adopted *pedagogical principles* and *learning hypotheses*, identifying the script's *intrinsic constraints* (bound to the script's core mechanisms) and the extrinsic constraints (bound to contextual factors). Extrinsic constraints define the space within which a script is modifiable because the related decisions result from arbitrary or practical choices, while intrinsic constraints set up its *raison d'être* and the limits of flexibility [1].
- Defining (as an explicit or implicit decision) the *structural model*, i.e., what conceptual notions (what "language") will be used to address the setting (e.g.: phase, group, physical space, group's ambiance, etc.). This may be fixed by the teachers' education, the fact that the teacher reuses some stuff (e.g., a known script), uses a platform that introduces certain notions, etc.
- Elaborating the *implementation model*, i.e., using the different notions to describe the script: the group-formation policy and dynamics; the task sequencing and articulation; the dataflow/workflow ruling the access to individual and collective data and/or to functionalities/tools; the physical space issues if any; etc.
- Elaborating the *platform specification* (definition of the technological platform requested properties, and the selection, adaptation or implementation of a platform).
- Elaborating the *student-oriented models*, i.e., what students will be prompted with: the *script presentation* (description of what students are supposed to do) and the *platform presentation* (description of the technological means).

Conducting[2] may include (items are not in strict order):

- Monitoring and analyzing learners' performance and, more generally, the setting unfolding.
- Recalling directions, answering questions, providing hints, refining the *student-oriented models*, adapting dynamically the *script presentation*, providing students with feedback, etc.
- Relaxing constraints or adapting directions within the scope of the extrinsic constraints. This may be a teacher's (or system's) initiative, or a response to a student's demand. It may consist in modifications of groups or schedule, tuning of the platform, etc.

Run-time scripting may include (items are not in strict order):

- Reconsidering the *intrinsic constraints*, as a way to adapt to the actual performance and, for instance, avoid a breakdown or take an opportunity.
- Reconsidering the *structural model*. For instance, it may be the case teachers use new "conceptual tools" to analyze the setting, now considering dimensions that had not been identified as important (e.g., ambiance, stress, emotions, safeguarding data or keeping leadership).

[2] Conducting-actions are related to the actual script, i.e., the primo-script as initially designed or the result of some run-time scripting.

- Reconsidering the *implementation model*, i.e., the way means are used. Many things may be open for the human-based dimensions (however, not everything is open: a teacher cannot go against some decisions or facts). What is related to a given platform is constrained by the platform's malleability[3]. Changing for another technology is an option, which may be easy or painful (e.g., if it leads some works to be lost). Another option is to change what is supported by technology and what is not.
- Reconsidering pedagogical objectives.
- Reconsidering the *pedagogic principles* underlying the orchestration efforts (or, rather, adapting to the actual unfolding the way the complex and often-contradictory decisions to be taken in pedagogical settings are balanced).

Conclusions

Orchestration is an interesting notion to be kept to the fore and be re-interpreted in the light of current technology and trends (which does not discard the interest of more ancient views). Within this context, I propose a conceptualization that disentangles orchestration technology and orchestrable technology, and defines orchestration as a combination of scripting and conducting. Moreover, I propose to differentiate primo- and run-time scripting. These notions, and their articulations, are interesting topics for TEL research.

References

[1] Dillenbourg, P., (2011), Design for orchestration. Position paper.

[2] Dillenbourg, P., Tchounikine P. (2007), Flexibility in macro-scripts for CSCL. Journal of Computer Assisted Learning, 23 (1), 1-13.

[3] Tchounikine P. (2008), Operationalizing macro-scripts in CSCL technological settings. In: International Journal of Computer-Supported Collaborative Learning, 3(2), 193–233.

[3] I refer here to the precise CS meaning of malleability, i.e., what can be adapted at run-time by the software users - here, the teacher or the students -, by opposition to "going into the code": the platform implementation can rarely be changed by a CS engineer during the session.

9. A response from F. Fischer & I. Kollar

No matter how we name it, we need it!

Frank Fischer & Ingo Kollar, University of Munich, Germany

Dillenbourg (2011) provided a thoughtful and critical analysis of the term "orchestration" that has over the last years increasingly been used in the context of TEL. His main claim is that - although the actual meaning of the metaphor may not be useful for a re-conceptualization of traditional and TEL classrooms - it has been used so intensively over the last years that the term will and should be continued to be used; however, there is no use of adopting the metaphor in a 1:1 fashion for re-conceptualization of traditional classroom practice. In our response, we challenge this view by pointing to six issues that we think the orchestration metaphor is useful to keep, because it leads us to think about educational practice and research in different ways - at least it should be kept until a better metaphor is found.

No matter how we name it, we need it! But don't drop the metaphor before you have fully exploited it!

Dillenbourg (2011) suggested to drop the metaphor and use orchestration as a new term with a new definition that should ignore the initial meaning of the term orchestration in music. We suggest to ignore Dillenbourg's suggestion at this point. The reason is that we do not feel that the metaphor has so far been fully explored. Once we have done so and find it useless or misleading, we could go with Dillenbourg (2011) anyway. However, the point for abandoning the concept has not yet come. Instead, thinking about technology-enhanced learning in classrooms as something that has to be orchestrated and arranged on different levels, with different participants, tools etc. still is a new perspective for research. Thinking of the teacher as adopting a similar role as a conductor has in an orchestra, for example, may lead to think more thoroughly about what technologies we could provide him or her with to make his role easier. Just as the conductor has a baton, the teacher may use different tools that help him in "keeping it all together". Dillenbourg (2011) listed a number of technologies that do a perfect job on this.

Music might be self-contained, teaching never is!

„Orchestration can (…) be defined as usability when the classroom is the user" (Dillenbourg, 2011, p. 7). The idea of equating orchestrated classrooms with usable classrooms is intriguing but we think it is missing one very important component: Usable for *what*? We think Dillenbourg (2011) is not so clear in this respect. Teaching should not be Selbstzweck. The classroom should be usable in the sense that (primarily) the participating students learn and are effectively supported in their learning. If we consider learning as a relatively consistent change in the participating learners' cognition, motivation, emotion, or behaviour, then the degrees of freedom for orchestration and for arrangement are reduced dramatically. Thus we argue for a functional redefinition of the concept of orchestration. Orchestration surely has some aesthetical facets – but they are not the core of it. Nicely designed technologies are helpful but it is not a priority to have nice technologies smoothly working and playing together in the classroom, unless they serve their main function: facilitating learning (of the learners).

Orchestration *precedes* the arrangement in the classroom – a process similar to transferring a TEL environment into a classroom setting?

In music the composer is responsible the orchestration, that is: assigning instruments to voices in a piece. In the process of “arranging”, conductors may deviate somewhat from the original orchestration if they, e.g., do not have the full range of instruments available in their orchestra.

What we really mean by orchestration is the transformation that takes place *after* orchestration by the composer – the process of arranging pieces of non-present composers by following a more or less specific set of rules. These rules are ideally consistent with the typical constraints of different types of orchestra out there. The rules that constrain this transformation ensure Werktreue (faithfulness to the original).

If the composer (or the school of composers) chose orchestrations or constrain deviations for the arrangements in ways that are not reflecting what typical orchestras out there have at their disposals the piece will hardly ever be arranged. Or it will be arranged in strange ways and questions emerge whether this is still the original piece at all. Dillenbourg and Tchounikine (2007) coined the term “flexible scripts” to emphasize the need for the teacher to be equipped with adaptable technologies that allows for an easy arrangement. The question now is what Werktreue is in the case of technology-enhanced learning. Without going into too much of a detail we suggest that Werktreue in TEL is about activating specific learning processes in the learners through the use of specific technologies (rather than displaying specific teaching activities).

Practicing needs to be distinguished from Performing

Applying the orchestration metaphor to re-think educational practice may not only expand but also constrain our thinking. For example, one problem of the orchestration metaphor seems to be that it makes us consider the actual learning process (see Dillenbourg’s definition: “Orchestration refers to the real time management of multiple activities and multiple constraints.”) rather than the design of the learning process that precedes the actual learning process. Certainly, the joint performance of a product (to an audience) is one important consequence of orchestration (although it is difficult to find analogies to what the product and the audience are for an orchestra in a classroom; see Kollar, Hämäläinen, Evans, de Wever & Perrotta, 2011). However, another important part is the process that precedes this performance. Along these lines, we think that it could be useful to differentiate a practice phase from a performance phase. Actually, some of the arguments that Dillenbourg (2011) puts forward seem to be concerned with the practice stage during which the teacher may assign different tasks to different students, group them in a specific way or interrupt group work by plenary or individual activities. This is similar to the job of the conductor during orchestra rehearsals. He may decide to only have the violins play a certain part of the score, while the rest of the orchestra is supposed to listen. Also, he may assign individual tasks to some members of the orchestra who obviously do not yet master their part of the score. After some time, he may have the whole orchestra play together to perform the piece. When thinking about orchestrating learning, we believe that it is particularly important to design such “practice” phases (probably much more important than performance phases, which may be individualized or collective tests). For example, a very relevant and not easy to answer question is how (i.e. in what sequence) plenary, small group and individual activities should be combined in the classroom. This has been the central question of the IKS (Internetkompetenz an Schulen; see Kollar, Wecker, Langer & Fischer, 2011; Wecker, Kollar, & Fischer, 2011) project which will shortly be described in the following.

In the IKS project, a 4.5 weeks curriculum unit on Genetic Engineering was designed in a collaboration between educational researchers, subject matter experts, and Biology teachers. The curriculum unit was used in a number of eighth-grade high school classrooms in Germany. The task for the students was to use 7 Biology lessons to develop a well-warranted position concerning the question whether Genetic Engineering should be allowed or not. To develop such a position, the students received a personal laptop computer that they could use to search the Internet for evidence and arguments. The curriculum unit consisted of three content-related cycles (cycle 1: economic aspects of Genetic Engineering; cycle 2: ecological aspects of Genetic Engineering; cycle 3: health-related aspects of Genetic Engineering) and each included three steps. In a first step, students were supposed to use an online library that offered Biological background knowledge on Genetics and Genetic Engineering. In the second step, dyads were formed that searched the Internet to retrieve information and evidence that could be used to form a position in the aforementioned debate on whether Genetic Engineering should be allowed or not. In the final step, a plenary discussion was led during which the dyads were supposed to introduce their arguments and uncover the sources of evidence for their arguments. Thus, already this sequence of three steps included learning activities that were realized on different social planes (Dillenbourg & Jermann, 2007) of the classroom (dyadic and plenary activities). However, we were particularly interested how step 2 (online search phase) needs to be designed to produce optimal learning gains with respect to the acquisition of online search competence. To do so, we developed and compared two different classroom scripts (i.e., instructional interventions that differ in the way they distribute learning activities over the social planes of the classroom): One classroom script located all online search activities at the small group level, i.e. whenever the task was to search the Internet for evidence, this was done in dyads. In contrast, the alternative classroom script that we investigated alternated between dyadic and plenary search phases, i.e. dyadic search phases were from time to time interrupted by plenary search phases in which the teacher modelled a successful online search with a student in front of the whole class (or two students modelled and the teacher commented on their procedure; see figure 1 for a graphical representation of the two classroom scripts).

The results of this study demonstrated that alternating plenary and dyadic learning phases led to higher levels of individual online search competence than having all search activities on the small group (i.e. dyadic) level. Even more, we found that the classroom script that alternated between the plenary and the small group level was more effective than a small group collaboration script that guided dyads through their collaborative online search by providing them with adequate prompts. To conclude, the sequencing of activities on the different social planes of the classroom in deed seems to matter. Thus, thinking of orchestration as a process that also includes a practice or rehearsal phase seemed useful to inform research on classroom and small group collaboration scripts in a TEL scenario.

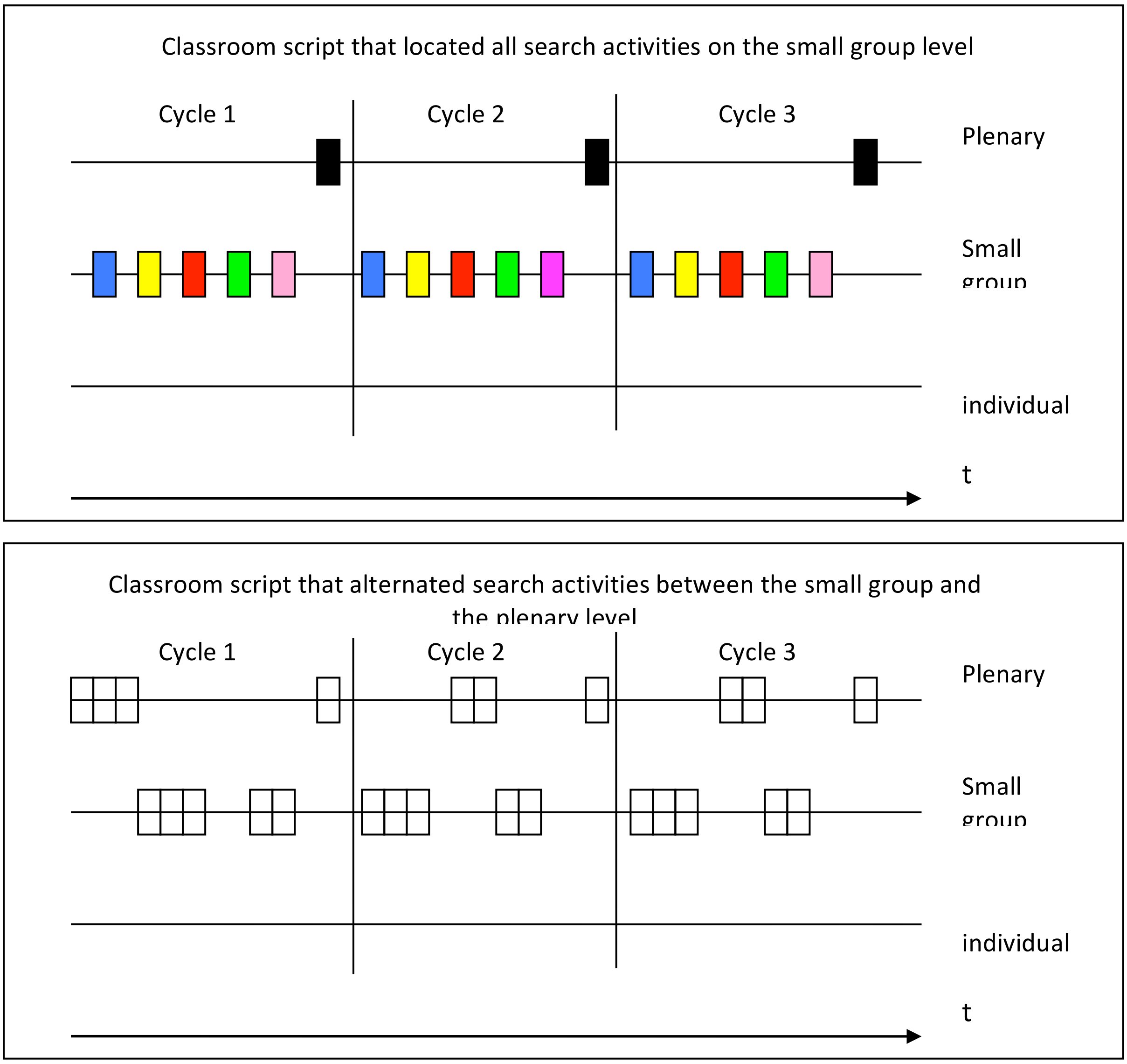

Figure 1. Graphical representations of the activity sequences in the two different classroom scripts. The boxes stand for different steps of the online search strategy students were supposed to adopt (blue = Sketch of initial argument; yellow = Selection of search terms; red = Selection of links on the hit list; green = Finding information on the web site; pink = Revision of initial argument; black = Plenary discussion).

Arranging as drawing on the heterogeneity of skills in the orchestra and in the classroom.

A good conductor will arrange a piece by drawing on the different strength of his or her specific orchestra. Orchestration in the classroom is about activating (or inhibiting) individual knowledge structures on collaborative learning activities. We have been calling this knowledge “internal collaboration scripts”.

Orchestration research in need for new research methods

We should admit that we are increasingly investigating multilevel phenomena and should open our methodology toolbox to collect some new methods to appropriately address this multilevel phenomena. Traditionally, qualitative approaches are applied to tackle complexities like this. However, recent years have seen the development of strong quantitative multilevel approaches that TEL research has not yet adopted. In addition, non-linear regression models are increasingly being used in the behavioural sciences to deal with the conceptually non-linear processes of developmental and learning.

Conclusion

We agree with Dillenbourg’s assertion that the orchestration metaphor is not the best one to describe traditional classroom processes, i.e. that it does not work all the time when describing teaching and learning processes that occur in a traditional classrooms. However, we still believe that thinking about equivalents to the components of an orchestra and the process of orchestration in traditional classrooms can lead to re-thinking educational practice as well as educational research. Of course, re-thinking education does not only refer to the use of technologies, but it includes it. Thinking about how we can make classrooms more similar to orchestras may lead us also to think more thoroughly and systematically about how technologies may be used in this enterprise. For example, although an audience is typically lacking in a traditional classroom, using the Internet for a class activity during which students publish their (joint?) products on the web so that everyone (or for example a partner school in New Zealand) can see what they have done and report on it may bring at least a virtual audience into the classroom. There are surely more ways in which technologies can be used to make the classroom resemble an orchestra. However, a systematic analysis of the different opportunities that TEL opens up in this respect is still missing, which - as we claimed at the beginning of this response - would make it seem premature to abandon the orchestration metaphor completely at this stage.

References

Dillenbourg, P., (2011), Design for orchestration. Position paper.

Dillenbourg, P. & Jermann, P. (2007). Designing integrative scripts. In F. Fischer, I. Kollar, H. Mandl &, J. Haake (Eds.), *Scripting computer-supported communication of knowledge. Cognitive, computational, and educational perspectives* (pp. 259-288). New York: Springer.

Dillenbourg P., Tchounikine P. (2007). Flexibility in macro-scripts for CSCL. *Journal of Computer Assisted Learning, 23*(1) 1-13.

Kollar, I., Hämäläinen, R., Evans, M. A., de Wever, B. & Perrotta, C. (2011). *Orchestrating CSCL - More than a metaphor?* Poster to be presented at the International Conference on Computer-Supported Collaborative Learning, Hongkong, China.

Kollar, I., Wecker, C., Langer, S. & Fischer, F. (2011). *Orchestrating Web-Based Collaborative Inquiry Learning with Small Group and Classroom Scripts.* Paper to be presented at the International Conference on Computer-Supported Collaborative Learning, Hongkong, China.

Wecker, C., Kollar, I. & Fischer, F. (2011). *Explaining the Effects of Continuous and Faded Scripts on Online Search Skills: The Role of Collaborative Strategy Practice.* Paper to be presented at the International Conference on Computer-Supported Collaborative Learning, Hongkong, China.

10. Synthesis

P. Dillenbourg, EPFL

There is some convergence among the viewpoints expressed so far. Orchestration appears as a useful concept to increase the impact of TEL on schools but there is much work to consolidate the concept itself and to turn it into tools and technologies. As a synthesis, I built a simplified concept map (Fig 1) from the different contributions.

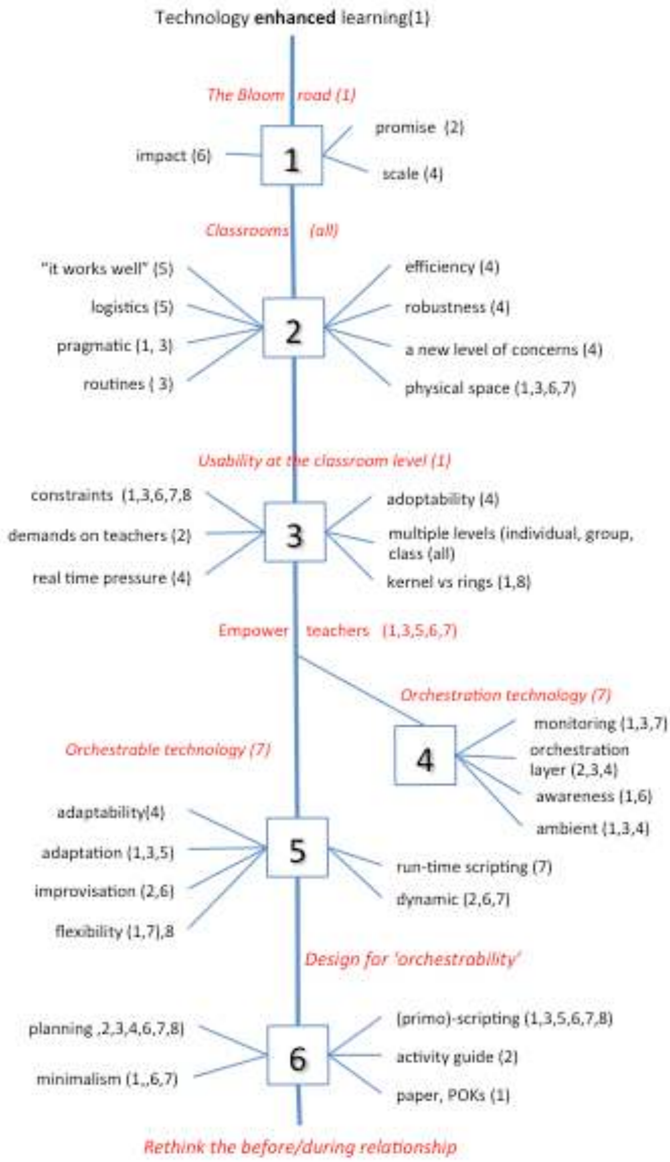

Figure 1. A concept map for the 'orchestration' debate

Let me describe this model (Figure 1) in 6 steps. The numbers refer to the authors (1= Dillenbourg, 2=Sharples, 3=Dimitriadis et al., 4=Roschelle, 5= Nussbaum & Diaz, 6=Looi, 7=Tchounikine, 8=Fischer & Kollar) and the steps to the boxes in the map.

Step 1. Several contributors share the initial observation that TEL has not yet delivered his promises in terms of impact on the school system (1,2,6), especially the difficulty to scale up (4) from small successful experiments to a broad impact. ("the Bloom road").

It is hence logical that the discussion focused on formal education: it does not exclude informal learning, but orchestration is bound to the specific concern regarding how technologies are used in classrooms.

Step 2. The contributors seem to agree that orchestration addresses the use of TEL from a very specific viewpoint ("a new level of concerns" – 4). While technology adoption have been -and should be- studied from social, cultural and psychological viewpoints (e.g. resistance to changes), the contributors stress the very practical difficulties in conducting TEL activities in classrooms: Nussbaum call them "the logistics", others use the word "pragmatic": we refer to a set of concrete issues that may bring a teacher to say that an approach "works well" in his classroom. The physicality of the classroom is stressed by several authors (1,3,6,7) although some of us (2,3) insist that the concept of orchestration does also apply to activities that occur outside the classroom (e.g. field trips) as well as on-line.

This set of practical issues is summarized by (1) as "usability at the classroom level". The ability for the teacher to walk between the tables to monitor what students do on their computer is a typical instance. For me, **orchestration is not a learning theory**: it does not address why students learn or don't learn but why it is hard to conduct TEL activities. Fischer and Kollar defend the opposite position in 8.

Step 3. The next step is to disentangle these practical difficulties. The contributors converge about the angle: they analyze TEL practices from the teacher viewpoint. Conducting a TEL session is described as a highly demanding (2,4) task, coping with multiple constraints (1,3,6,7). The point is that TEL research has focused on the design of the core learning scenario ('kernel'-1) but neglected these practical constraints. Fischer & Kollar insist that the kernel should nonetheless remain the main design preoccupation: I agree but what is novel in 'orchestration' is to care for the rings.

Some consensus emerges about the need to facilitate teachers' work, i.e. help them to cope with these many constraints and to manage the ring activities. This need has been phrased as 'empowering teachers': this should not be understood as a returning to an authoritarian lecturing style but as giving teachers the same degree of control for conducting a TEL-based scenario than conducting a TEL-free scenario.

Tchounikine (7) introduces at this point a useful distinction between orchestration technologies and orchestrable technologies.

Step 4. An orchestration technology is a tool for visualizing the activities of many students, some kind of teaching cockpit. These visualizations (Nussbaum, Looi) differ from the work on student modeling or educational data mining by showing simplified aggregated data, displayed permanently without a need for the teacher to make queries of even to navigate. Contributors seems to converge that these so-called 'orchestration layer' (2,3,4), aimed at easing teachers' task, may actually make his work more complex. Strict functional minimalism, as in an ambient awareness tool (1), is a condition to avoid this pitfall.

Step 5. An orchestrable technology is a technology that provides teachers with the power of changing at any moment the scenario that they have prepared. The keywords are adaptation (1,3,4,5), flexibility (1,7), dynamic planning (2,6,7) or run-time scripting (7). Adaptation, a central TEL concern for 3 decades, usually refers to modifying the learning activity based on the learner's behavior. Orchestration requires a broader scope of adaptations, namely those required by external events such as a network failure, late coming students, mistakes in the material, etc.

This leads to the central tension between planning and conducting an educational scenario. This tension reflects the ambiguity of the word orchestration, as writing the musical play as well as conducting an orchestra.

Step 6. This planning/enactment tension is as old as instructional design but orchestration calls for a drastic increase of flexibility in the enactment phase. There are many technical difficulties in programming flexible but yet not completely open scenarios. New architectures and models should be developed for facilitating orchestration, such as paper-based interfaces (1,2) and tangible workflows. At this point, the authors diverge. For Looi (6), orchestration is per se 'unplannable'. For Tchounikine, we have to dissociate forms of scripting before and during the lesson. For Roschelle (4), the distinction between what is planned before the lesson and what is modified during the lesson is becoming obsolete. It should be reconsidered under the light of todays' technology. I agree: 'orchestration' requires a new regard on the ratio between instructional planning and conducting a lesson. This is the main implication of 'orchestration' for TEL researchers.

In our workshop, we discussed the tension between two facets of classroom life, routines and improvisation. Daily school life is based on a mosaic of routines, both for teacher's behaviour and student's behaviour. It usually takes some time to set up these routines but, once they are set up, they make everybody's life easier; they reduce the 'global orchestration load' (see next section). At the same time, real time classroom management requires some degree of improvisation. A high degree of improvisation is certainly too adventurous for most teachers, it is somehow risky to improvise while managing 30 students or more, but some improvisation is necessary. A challenge of orchestrable technologies is to allow fast switching between routine and improvisation modes. A jazz jam session might have been more suitable than 'orchestration' since what is referred to as 'improvisation' relies of subtle changes on highly trained routines.

There is disagreement between contributors with respect to the status of the word 'orchestration'. I proposed to use 'orchestration' as a label, i.e. to drop any metaphorical reference to music. My goal was to focus the discussions on the concept, i.e. the difficulty of classroom management, rather than on the analogy per se. Several responses defend the interest of the metaphor. These discussions could be summarized by the orchestration square (Figure 2). Using orchestration as a metaphor questions to the validity of the arrows a and b (8) or of the arrow e (7): is there an added value using vertical arrow c as a metaphor for describing d ?

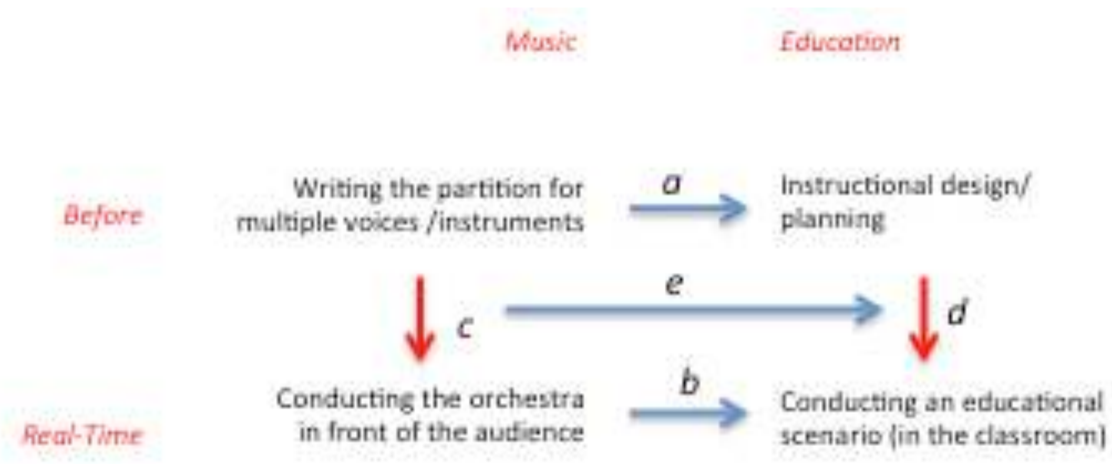

Figure 2. The orchestration debate square

It is interesting to see the emergence of a shared notation with 3 layers: individual, group and class-activities. The oldest slide I found with this graph is from March 2003, in a workshop on 1:1 TEL in Chungli, Taiwan. It was an adaptation, for schools, of Vygotsky's planes: intra-personal, inter-personal and social. This notation progressively became part of the culture of specific working groups in Kaleidoscope, a previous European Network of Excellence, which proves their impact on the community. The fact that it looks like a simplified music partition was perhaps a precursor of the orchestration debate. For the sake of completeness, we should add two upper layers, the community layer (the school, the parents, the neighborhood,…) and the world (e.g. school activities that broadcast their results on the web).

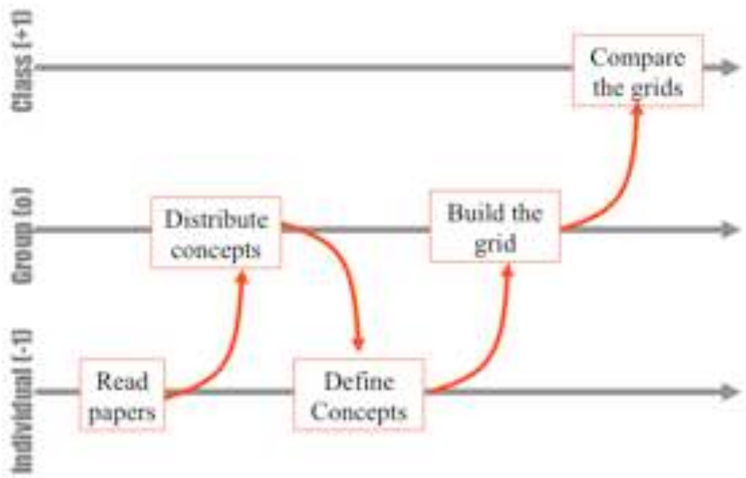

Figure 3. A shared notation for integrated classroom scripts (2003)

Fischer and Kollar identified a deeper disagreement: **should we the focus on teacher activities or on student learning?** Of course, we should focus on student learning; teacher activities are only instrumental to student learning. However, when teachers (and most of us are teachers as well) say "it works well", does they refer to learning gains? When your kids get bad grades at school, what do their teacher tell parents: "I am sorry, my scenario was not very effective last week"… or rather something like "You kid did not concentrate much on school work last week" or "Her work decreased in quality and quantity" etc. My experience is that, for many teachers, learning achievements mostly depend upon how serious / concentrated / intelligent / hardworking kids are and not upon their own effectiveness. Hence, the label « it works well » rather refers to things such as : “I covered the curriculum within the time constraints”, “the kids were with me", ”they participated well”, “the level of noise and order in the class was acceptable”, “ the amount of work for them and for me, were reasonable”, etc. In summary, « it works well » refers to the management of the many constraints listed in this document more than to learning gains. Should educational research and teacher training aim at changing this? Probably, but, « it works well » will remain a ‘sine qua non’ condition for « they learn ». The ‘orchestration’ movement – if I may call it so - aims to fulfil this condition because TEL that do not work well, are abandoned at the end of research projects, as soon as educational researchers leave the school. This does not mean that “they learn” is not anymore the most important research question, but that “it works well” should also be recognized by the TEL research community as a **fundamental question,** not as implementation details.

11. Technologies and Orchestration.

Pierre Dillenbourg, EPFL

One goal of this deliverable is to review the technological evolution in TEL. Are there some specific orchestration technologies? Obviously, the trendscouting work reported here is not bound to a specific technology but to a specific way to design technologies. The question remains nonetheless to see if some technologies would facilitate orchestration. To answer this question, I use Tchounikine’s distinction between orchestration technologies and orchestrable technologies.

Orchestration technologies are tools that assist the teacher in her difficult task of orchestrating integrated classroom activities; they are orchestration prostheses. A simple watch could be considered as an orchestration tool since it facilitates time management. Most orchestration technologies that have been mentioned are monitoring tools that help a teacher to maintain a –simple- representation of the students’ activities. There are not specific environments, but specific functionalities plugged into TEL environments, namely real-time aggregated visualizations of the activities performed by the learners. They are in the spirit of learner modeling or ‘educational datamining’ but, since data are computed at the class level and have to be interpreted in real time by the teacher, orchestration tools propose much simpler visualizations than scholars working on learning paths. The Lantern (see contribution 1) is original on two dimensions: first, it performs a visualization of activities that are not computer-based; second, it does not aggregate data on a central display but on distributed devices. Soon will emerge new orchestration tools for co-present classrooms such as *attention monitoring tools.* When a teacher perceives that the audience is losing attention, she should react promptly. Some teachers are not very good at detecting these losses of attention. A nice orchestration tool, using a high-resolution camera placed in front of the classroom, would predict student’s level of attention by capturing gaze movements and head positions and provide the teacher with a simple indicator of global attention.

Beside these technologies for orchestration, the key technological question is to understand what makes technologies *orchestrable*. As stressed in this document, a key aspect of orchestrability is *flexibility*: how easily can the teacher modify on the fly what (s)he has prepared. For instance, mesh-like environments or toolbox environments that provide teachers with a palette of tools that can be used in any chronological order are more orchestrable than CSCL macro-scripts such as ArgueGraph, which rely on a pre-defined sequence. Not surprisingly GroupScribbles is often cited when referring to orchestration: it relies on very simple mechanisms to support individual group and class activities. There is unfortunately a tension between flexibility and integration. Since integrated learning involves different activities that are “integrated” at the data level, *workflows* are necessary to make a technology orchestrable. The reason why paper-based interfaces constitute a very orchestrable technology is precisely because they bypass this contradiction, making the workflow visible and hence modifiable in real time.

But flexibility is not all. For instance, interactive tables and whiteboards could be considered as orchestrable because they take into account the physicality of the classroom. However, even if tabletop environments support interesting learning activities, they make orchestration quite difficult for several practical reasons. In most cases, one table is available per classroom, which implies that the teacher will have to 3-4 kids who work around the table while 20 other kids do another activity elsewhere. Many tabletop technologies require the room to be quite dark, which increases the difficulty of classroom management. These are, as stressed before, small concrete problems, but they may spoil the lesson. Other technologies raise other problems. Instead of enumerating them, I propose to consider the ***global orchestration load*** *(GOL)*, i.e. the total increase/decrease of teacher's effort required by a technology for orchestrating integrated classroom activities. The GOL includes the effort necessary before/after the lesson for preparing the scenario, but also for setting up and removing the equipment, for providing feedback or grading assignments, for obtaining authorizations if needed, to move to another room or place if needed, etc. Additionally, the GOL includes of course the extra effort, while conducting the lesson, for satisfying all the constraints listed in (1): discipline, engagement, time, assessment, etc.

For these reasons, technologies such as Web2.0 tools or digital whiteboards are per se not good or bad for orchestration. Specific *design choices*, both concerning the software and the hardware, may increase or decrease the GOL in different classroom contexts. Some design guidelines emerge nonetheless from this document. The main guideline is minimalism, i.e. to avoid adding functionalities in TEL environments that are not strictly necessary, since they might increase the GOL. Using ambient interfaces, an instance of minimalism, potentially decreases GOL since these interfaces do not require the teacher to maintain attention of something else than his students. Flexibility decreases GOL because it decreases the cost of on-the-fly modification. A minimal, semi-ambient, light, flexible approach to digital tools is what I referred to as *modest computing*.

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