System orchestration support for a flow of blended collaborative activities

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Abstract: The introduction of portable devices in education opens up new possibilities for Computer Supported Collaborative Learning by providing advanced learning scenarios with activities in different spatial locations. However, organizing and structuring collaborative learning adaptive flows in these innovative scenarios represents also a workload for practitioners, which hinder the adoption of these technologies. As a step forward to alleviate this workload, this paper analyzes the limitations and bottlenecks detected in an actual collaborative blended learning experience carried out in a previous study and proposes a technological solution for solving them. The resulting solution is presented as a concept proof consisting of a Unit of Learning suitable to be instantiated with IMS Learning Design and complemented by a Generic Service Integration system. The paper also discusses to which extent the proposed solution covers the limitations detected in the previous study and how useful could be for reducing the orchestration effort in future experiences.

Keywords: IMS Learning Design; blended learning; CSCL; GSI; service integration

I. Introduction

Portable devices have impacted multiple aspects of our everyday life. In education, the potential of this technology is seen by researchers and practitioners as a chance for expanding current educational scenarios and exploring innovative learning methodologies [26]. Particularly in the area of Computer Supported Collaborative Learning (CSCL), the introduction of portable devices opens a new debate about how this discipline is going to evolve [10].

Significant research effort has been devoted to introduce portable devices in learning experiences and to understand how they might enhance current educational settings. Some works benefit from the mobile and content delivery capabilities of this technology to generate learning settings enabling learners to work and collaborate in different spatial locations beyond the class. For example, Facer et al [2] propose a mobile gaming experience in which children are invited to understand the animal behavior in a savannah in direct physical interaction with this space. The findings of this study show that this innovative experience increased the self-motivation of children. Another work by Ruchter et al describes an experience using mobile computers as a guide for supporting environmental learning [1]. The results show that using these computers as mobile guides can lead to an increase in knowledge about the natural environment and an increase in students' motivation to engage in the educational environmental activities. Both studies propose activities in which students interact with course material with their hand held devices in different spatial locations and introduce a new concept of learning in which activities are no longer limited to the classroom space.

A study by Park et al. states that "mobile learning activities could provide a better learning experience by establishing the conditions for optimal flow" [4]. This idea relates with the CSCL concept of *orchestration*. Orchestration is defined as the process of structuring learning flows for achieving potential effective learning outcomes [11], and the path followed by course participants during the whole activity enactment is called *learning flow*. According to Roschelle and Pea "learning content's performance is optimized when it is orchestrated with a pedagogical sense" [10]. One of the proposals to organize and computationally support these learning flows are the so called "scripts" [3, 12, 13]. CSCL scripts manage resources and deliverables, define roles and phases and enable specific interaction in order to guide collaborative processes for producing situations of effective learning [14] by facilitating and reducing the coordination efforts of teacher and students [6, 5, 16]. However, when these scripts combine activities supported by portable devices with activities taking place in different spatial locations, the orchestration process becomes more complex. In such type of scenarios it becomes particularly challenging tracking students' progress [4]. This hinders the establishment of the relations within activities and makes the management of the collaborative learning flow more difficult. As a consequence, the orchestration of collaborative learning flows in such scenarios translates into an increase in the teaching staff workload.

The results of a previous work carried out by the authors of this paper in a real educational context evidence this workload [8]. The work presents a case study of a collaborative blended learning experience that combines mobile based activities with in-class sessions. Despite the encouraging results, the enactment of these types of learning settings imposes a significant workload on the teaching staff. As a consequence, one of the conclusions of the study proposes automating some aspects of the experience enactment for future editions of the course. The work presented in this paper is based on the above-mentioned previous experience. The goal is to present the proof of concept of a technological setting that automates some of the orchestration tasks of this experience. As a consequence, the teaching staff effort is expected to be reduced thus facilitating the replication of the experience with a reasonable cost in future editions. With this aim, we created a scripted learning flow implemented in a Unit of Learning (henceforth simply UoL) for orchestrating the activities and automating management duties. The UoL is compliant with IMS Learning Design (IMS LD) [7] and extended with Generic Service Integration (GSI) [9]. As a conclusion, we discuss to which extend these technologies can overcome with the limitations detected and how useful might be in similar situations.

The rest of the paper is organized as follows. Section II describes the scenario from the previous experience and its main limitations. Section III details the system architecture prototype built as a proof of concept to automate the orchestration process of this scenario. Finally, Sections IV and V discuss how the proposed scripted flow is envisaged to solve the limitations of a previous study and help reducing teaching staff workload on similar experiences.

II. LIMITATIONS ON THE ORCHESTRATION OF A REAL EDUCATIONAL EXPERIENCE

This section is divided into two parts. First, the learning experience carried out in a previous work by the authors of this paper at the Universitat Pompeu Fabra (Barcelona, Spain) is presented. In the second part, the experience is analyzed by re-using the data of the study and the qualitative results obtained. As a result, we identify the main limitations regarding the orchestration process.

A. Scenario: meeting the campus together

The CSCL experience was carried out with 74 first -year ICT engineering students enrolled in a mandatory course called Introduction to Information and Communication Technologies. The aim of the course is to give a global vision of the University and its resources, and an introduction to the professional world of ICT industry. The CSCL activity started the first day of the 2009-2010 academic years and continued during the next two weeks. The scenario was organized in three different phases following the learning flow defined by the Jigsaw Collaborative Learning Flow Pattern (CLFP) [22, 23].

The first phase consisted in an individual exploration of the campus. We named this phase “Discovering the Campus”. To support this activity 46 NFC (Near Field Communication) tags were distributed around the 5 campus's buildings. These tags contained information about the place in which they were located. Students were equipped with NOKIA (N6131, N6212) mobile phones which included an embedded RFID reader for accessing the information stored in the tags. Students had 30 minutes to freely explore the campus. All the information regarding the sequence of tags accessed by each student was stored into a log file. After the visit, students had to fill in a Google Forms questionnaire indicating which buildings had visited and which seemed to them the most interesting.

The second phase was called “Explaining the campus”. In this phase, students were grouped in “Building's Expert groups”. Each expert group was associated to one of the 5 campus buildings and had 4 or 5 members randomly chosen from the students with similar building expertise level. To define the students' building expertise the teachers considered two sources of information: (1) the log files obtained during the exploration and (2) the answers to the Google Form questionnaire. The activity for these teams was to create a presentation explaining the main characteristics of the building assigned and upload it to the Moodle Platform of the University (henceforth Moodle).

Finally, the third phase was called “Reflecting about the campus”. For this activity, the teachers uploaded all the presentations from the previous phase to Moodle. Students had to access and review all the presentations and answer an individual test including questions about the whole campus. This last activity was carried out in a 25 minutes session in a classroom with PCs.

B. Orchestration tasks and limitations detected

All the orchestration processes of the case study were carried out by two teachers and one researcher. The activity was technologically supported (NFC tags, mobile phones, Moodle) but there was no system that automatically integrated the whole process. This translated into some of the orchestrations tasks being done *by hand*. It follows a detailed explanation of teacher tasks in each phase. The focus of this paper is on those orchestration aspects that were more demanding and time consuming. A detailed description of the activity design and preparation tasks can be found in [8].

The task for the teachers in the first phase was to store the log files once the students finish the visit of the campus. Due to the number of students and the number of available devices, some of the students had to share a device for the visit. To identify which data log belonged to which student, teachers annotated the time when a device was given to a student or pair of students. This information was used later to make the correspondence between the log files and the students and produce a log file for each of the students participating in the experience. The files were uploaded to a computer via Bluetooth connection.

In the second phase, teachers had to form the building's expert groups. As explained before, the expertise was measured taking into account the number of tags per building visited by each student and the preferences indicated in the questionnaire. This was the most complex and time consuming task. One of the teachers of the course stated: *“Once the whole activity was set-up, I think it was more a matter of complexity than of difficulty. The logistics was the more demanding issue: creating groups, informing students about the groups, orchestrating their tasks depending on the groups, managing and analyzing their outcomes in order to propose them the following tasks, managing their outcomes in order to facilitate the assessment of their learning, etc*”. A set of limitations in the orchestration process were detected in this phase. First, the teachers manually analyzed all the log files created during the visit. Due to the number of students (74) this part was very time consuming and the process had to be reviewed three times by the two different teachers and a researcher to avoid errors. This task required 3 hours. Second, in the analysis of the preference questionnaire, the recommended building was considered the preferred one. This was carried out approximately in 4 hours. Students were divided into two groups for the regular lecturing sessions. For the described experience, students from both groups were randomly mixed. Combining people from these groups also posed some problems. On one hand, students could not contact easily their class mates because they did not meet face to face in the classroom. On the other hand, because the activity took place during the first two weeks of the course, there were students dropping out the course before the final presentation so some groups had to be rearranged. All these group adjustment were carried on by the teaching staff using e-mail for communication.

In the third phase, the task of the teachers consisted of uploading the students' presentations to a public repository in Moodle and make students complete the final test. The teacher organized the presentations per building and created one folder for each group in the public repository. The test was uploaded to the platform and the teachers had to control that all students had answered the test. This activity was carried out in a session with PCs.

Finally, the teachers organized the workflow using Moodle. They used the platform to inform students of the steps for the next activities, and e-mail to inform when the description of a new activity was available. However, other activities in the course were also carried out in parallel during this period (and published in Moodle) and students had problems to have a unified view of the scenario.

Another aspect to highlight is the scalability of the activity. 421 students were enrolled in the course. However, due to the complexity in the activity orchestration, only a group of 74 students performed the mobile-based activity. The rest of students visited the university on their own.

In summary, the evaluation of the case study detected the following limitations:

1) Students' data analysis: Manually analyzing the log files was hard to carry out without errors. Also combining the preferences and the log file results for assigning the students expertise is complex and very time demanding.
2) Expert group management: Creating and managing the expert groups was very time demanding because of the instability due to drop outs that characterize the first weeks of the course and mixing students from the two lecturing sessions.
3) Activity workflow: Moodle does not facilitate the integration of the activities to create an orchestrated view of the learning flow.
4) Scalability: Without technological support, these activities are very costly to carry out for a large number of students. The data analysis becomes very complex.

III. Proposed Scripted Orchestration

This section presents the technological solution developed for dealing with the limitations highlighted in Section II.B. The proposal is to use a computational script as the orchestration mechanism for automating the most demanding tasks. The result is a Unit of Learning (UoL) (compliant with IMS LD and complemented with GSI) that structures the learning flow of the scenario. Additionally, the proposed UoL (with minor changes) could be used for supporting analogous learning flows. This solution is a proof of concept to show that teaching staff workload can be significantly reduced in any learning situation which combines collaborative activities in different spatial locations supported by portable devices.

A. Course flow management technologies

One of the best-established modeling languages used to computationally represent learning flows is the specification IMS Learning Design [7]. It provides a framework to design and deploy a wide range of pedagogical models, which includes collaborative and blended learning. IMS LD is constructed upon the metaphor of the theatrical play: different actors play different roles. Each *role* is assigned to a set of *learning activities* that may occur in sequence or in parallel, depending on whether they are organized in *acts* or *structures*. Each activity takes place in a given *environment*, which consists of a set of *learning objects* and/or *services*. The concept of role allows complex collaborative learning models to be expressed by IMS LD [18], while the existence of *properties* and *conditions* makes possible the design of strategies based on adaptive content [19].

Natively-defined services are limited to e-mail facilities, conference, monitor and index. In practice, available services are not able to support complex blended learning flows, where different tools are used in different scenarios. Generic Service Integration (GSI) [9] proposes a framework to include any kind of web-based tool in the context of IMS LD courses, making possible to adapt the flow depending on students' behavior on the included tool. For the purpose of the work presented in this paper, GSI has been used to integrate specialized data management tools as part of the learning flow. We have used an on-line web spreadsheet provided by Google [28] to administer students' data and to automatically create groups.

The integration of Google Spreadsheets in a UoL can be summarized as follows [9]: students access a questionnaire (an HTML form) through a hyperlink located in the *environment* of an activity; on the other hand, teachers own a spreadsheet populated by student's responses, where each row contains data from a single student. Teachers can manipulate the spreadsheet arbitrarily so that they produce a value suitable to be mapped to an IMS LD property. Then, IMS LD retrieves the data contained in the spreadsheet and the appropriate properties are updated.

The inclusion of spreadsheets in IMS LD courses serves a double purpose. First, it provides support for assessment, the absence of which is one of the weaknesses of the specification. Assessment is made possible by including HTML questionnaires and using the responses to adapt the course flow. Second, it offers a well-known method to manipulate data, substituting the complex calculate element in IMS LD, which hinders the creation of mathematical formulas based of questionnaire responses.

B. Course flow details

The script was designed to support five working groups, whose number of members was set to five. As a result, 25 is the number of learners considered in the design of the learning script. The number of teachers is not restricted. We will refer to all teaching staff members as simply *the teacher*.

The course follows a blended learning approach: students receive the information through the computer; some of the activities are done on-line and the remaining ones are offline. An overview of the course flow is show in Figure 1.

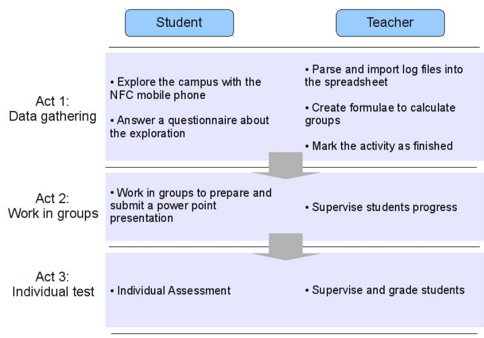

Figure 1. IMS LD Mapping of the original flow.

First phase: Discovering the campus

Two types of participants take part in the course: learners and teachers. These are the *roles* defined in the UoL. Although the learners are divided into groups, there still is a single role for all of them. This is because roles are populated at the beginning of the course, and therefore at design time there is not enough information about the number of required groups. This division is performed in a later step using *local properties*.

During the first act, learners visit the campus and acquire knowledge they will use in later activities. They perform the visit with a NFC mobile phone as described in section III. Once finished, they fill in a questionnaire to show their acquired knowledge of the campus.

Both, the answers to the questionnaire and the mobile activity logs, are stored in a Google Spreadsheet. The former are stored automatically, but the latter follows a different path shown in Figure 2. When a student finishes the activity, s/he is requested to use the resulting log file as the value of a file property. All student logs are stored in the same folder and are easy to manipulate. Furthermore, because files are related to their owners, it is also possible to easily identify which log belongs to which student. The regular structure of the log files allows automatic parsing. A script performs the log analysis and produces a *csv* file with a summary of the events generated by each student. This summary contains, for each student: (1) the number of tags accessed per building and (2) the building expertise, which is the building with the maximum number of tags accessed. This summary can then be uploaded into a Google spreadsheet. The process to generate this summary and upload it to the spreadsheet is done by the teacher and take place when all the students have finished their corresponding activities.

The spreadsheet then contains all the data from the logs (time and tags accessed by each student) and questionnaires (close and open questions about the campus buildings). At this point, the teacher manipulates the data so that the output of the activity is finally produced. The calculated output is a number (from 1 to 5) assigned to each student representing the building's expert group. All values are calculated by the spreadsheet, which has been previously modified with the proper criteria. The formulas in the spreadsheet require numeric values, and as a consequence the original questionnaire was modified to include closed response questions to process results automatically. The questionnaire includes three types of questions: (1) a multiple choice option in which the students select the building they have visited, (2) a true-false question related to each building and (3) a Likert-scale question to evaluate each building. The use of closed response questions solves two problems: first, offers the possibility of automatically computing the students' preferences. Second, provides the teacher with an easy mechanism to evaluate the students'.

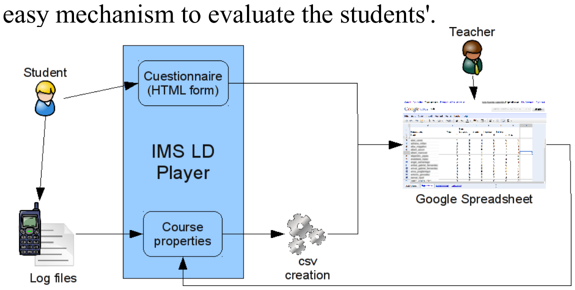

Figure 2 Data flow for group assignment automation

The criteria to group students considered data from questionnaires and log files. However, the absence of one of these sources was also supported. This fact provides a degree of flexibility to the course flow. For instance, students who could not perform the activity "Discovering the campus" will find their corresponding group in the next phase. This requirement is also supported by enabling the teacher to overwrite the groups assigned by the spreadsheet formulas.

Once the grouping phase has finished and no more group changes are expected, the teacher marks the activity as finished. This action triggers data synchronization between IMS LD and the external spreadsheet. When IMS LD properties obtain their value, conditions are evaluated and the course flow is adapted appropriately. There are two types of properties whose value is assigned:

- Each student has a property called *group*. The value is a number (from 1 to 5) that says in which groups the student has been placed.
- Each group has a property called *members*, which contains the team member names. This value is used to increase student awareness.

Second phase: Explaining the campus

The second phase of the course flow has been modeled as an IMS LD act: all course participants start at the same time. The act adapts its contents depending on which group the student has been related to. There are three issues to be solved by the course flow:

1) Which tasks corresponds to each student?

2) How do students know who their partners are?
3) How do students submit their presentation?

To solve the first question, the course flow has been modeled with five different activities, one per building's experts group. The visibility of these activities is controlled by property values, so that only one of them will be shown to each student. In practice, students receive the activity description that corresponds to their group, and they see no information about the other groups. Each activity description shows the *members* property of the group. Therefore, students are aware of who are their teammates.

The presentation submission has been modeled as a local property whose value is set when students upload a file through a form included in the activity description.

Third phase: Reflect about the campus

In this phase, the delivery of the previously submitted presentations requires no intervention from the teaching staff: file properties are directly accessible from the statement. Thus, students may review all the presentations and access to the final assessment task.

The final assessment is an IMS Question & Test Interoperability (QTI) test [27]. Students access it through a link in the UoL and login to the QTI server. The QTI test is composed of 5 questions: 3 common QTI questions (Multiple Choice, Yes/No and Multiple response) and 2 Google Maps-based QTI questions [25]. For these questions, students locate their answer in a Google Maps map.

IV. Discussion

Students data extracted from the empirical study presented in section II were used to simulate the enactment of the scripted orchestration proposed in section III. This section analyzes whether the solution solves the limitations observed from the experience: the expert assignments process, the expert groups management, the activity workflow and the scalability. A simulation was performed with a set of data consisting of 74 log files. Since the questionnaires were modified to fit in the proposed orchestration, the simulation did not use data from the empirical study. Figure 3 shows the results of the analysis of the 74 log files.

Both the module for automating log files analysis and the numeric questionnaires solved the main limitations of the students' data analysis. On one hand, this solution may strongly decrease the time spent by the teacher in analyzing all the log files. On the other hand, this automatic approach might support the teacher in the assignment of students' expertise by diminishing the number of errors when doing this process manually. Moreover, this approach also provides the teacher with the possibility of modifying the automatic building assignment. Therefore, it offers a flexible semi-automatic system for analyzing log files and managing the students' building assignments effectively.

The proposed semi-automatic solution relates the numeric lists obtained from the analysis of the log files and the answers to the questionnaire. The resulting values are used to generate a ranking of students per building that is shown to the teacher in a spreadsheet. The building assignment is done following the order established in the rankings lists and associating a number from 1 to 5 to each student. This semi-automatic group formation solution facilitates the teacher's grouping tasks alleviating the time investment. At the same time, this approach provides the user with a flexible mechanism to easily adapt the groups to the actual context of the activity. Despite this work does not explore different types of adaptive learning material, the presented approach allows adaptive strategies such as the assignment of personalized learning paths, without increasing teachers' management duties.

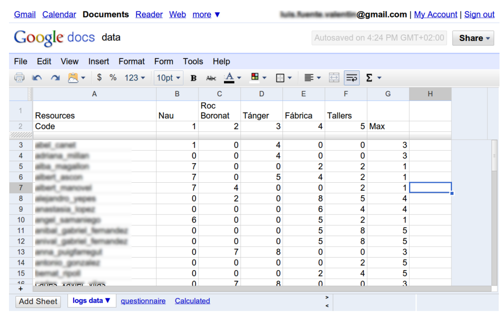

Figure 3: Student activity data imported from the 74 log files.

The workflow is captured and delivered using IMS LD. The activity tree and activity content, is adapted for each student who receives, at the end of the course, a complete view of the learning flow.

The scripted course flow presented in this paper has been designed to support 25 students. In the course flow, manual interventions of teaching staff are: (1) Copy log files to the folder where they will be parsed; (2) Import the resulting *csv* file to the spreadsheet; (3) Insert a set of spreadsheet formulas to calculate grouping criteria; (4) Mark acts as finished when corresponds. From these actions, (3) is the only one requiring significant time. However, its completion is required only once regardless of the number of course replications. As a result, the learning script can be instantiated several times, with a low impact in teachers' workload allowing scalability.

V. Conclusions

This paper presents a proof of concept of a technological solution that supports the automatic enactment of experiences requiring the orchestration of a collaborative learning flow, supported by different computing devices, involving different spatial locations and a large number of students. The motivating example has been drawn from a real experience that presented promising results in terms of students' motivation and achieved learning but imposing a severe workload on the teaching staff.

The proposed orchestration was captured into a UoL codified with IMS LD and GSI. The use of GSI to integrate services in the context of the UoL allowed the learning flow to coordinate the use of different technologies such as NFC, Google Spreadsheets and QTI. In the designed course, a semi-automatic process of data acquisition and group formation complements the group-dependent scripted delivery of the learning material. The enactment simulation with the proposed script showed that this solution would provide significant reduction of teaching staff workload. The major limitations of the previous experience disappear with the semi-automatic orchestration of the learning flow. As a conclusion, the presented solution sheds some light on how technology can facilitate the orchestration process of complex and innovative collaborative learning using portable technology such as smart phones. Moreover, in order to test the feasibility of the proposed solution the authors of the paper are currently implementing an instance of a UoL to be enacted in the fall of the next academic year 2010-2011.

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