Chapter 5
Towards an Architectural Approach to Supporting Collaborative Seamless Learning Experiences

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1 Introduction

Over recent decades, there has been increasing interest among researchers and educators in the design and practice of educational activities that enable opportunities for collaborative learning. Growing interest is currently being shown in activities offering new educational opportunities that are exploitable across contexts and settings, including those that can be exercised in various social settings, anywhere and at any time. Teachers and students can exploit these new opportunities for innovative and educational experiences, using various Web and mobile technologies as a means of supporting innovative modes for their educational interactions (Huang & Chiu, 2015). These types of educational activities demand deployment efforts that emphasize the challenges related to the design and implementation of these types of educational activities, executed seamlessly across contexts and settings.

Communities of researchers and practitioners recognize the opportunities that are emerging due to the special nature of these activities, including their richness of context and settings that provide teachers and students with new opportunities to benefit from authentic learning experiences wherever and whenever available.

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In addition, these communities also acknowledge the challenges they would need to overcome in the design and deployment of activities with these characteristics (Baran, 2014; Osang, Ngole, & Tsuma, 2013; Sharples, 2013).

Our ongoing research focuses on approaches enabling the transformation of learning requirements into mature design and deployment for educational activities, which can later be shared and reused (Kohen-Vacs, 2016; Kohen-Vacs, Milrad, Ronen, & Jansen, 2016). Specifically, we address various types of actors, including the designers and users (teachers or researchers) required for certain aspects of these activities, and including the physical location in which they are conducted, the time at which they are conducted and the social organization of their participants. No less important is our emphasis, shared with other researches, on the variety of learning opportunities and the best ways to enable teachers and students to interact with them during these activities (Al-Emran, Elsherif, & Shaalan, 2016; Muñoz-Cristóbal, Asensio-Pérez, Martínez-Monés, & Dimitriadis, 2015).

These considerations illustrate the complexity of these activities and emphasize the role of the technological means necessary to alleviate the abovementioned challenges (King, Gardner-McCune, Vargas, & Jimenez, 2014). These aspects of educational activities, including educational, administrational and technological concerns, were explored by Wong and Looi (2011) in their research work focusing on mobile-assisted seamless learning (MSL) dimensions. More recent research published by Milrad et al. (2013) suggests ways in which novel educational design patterns, mobile technologies and software tools can be used to design future educational activities and technological solutions that can support seamless and mobile learning. Prieto et al. (2015) also recognize concepts related to MSL dimensions and consider novel educational interactions. In particular, acknowledgment of such dimensions could be used while intending to support complex interactions by a series of interrelated software components, each offering support for some of the above-mentioned concerns. Furthermore, these components could be conveniently organized in an overall architecture providing comprehensive support for the enactment of these educational activities. Such an architecture should aspire to provide an optimized, meaningful and seamless experience for teachers and students during their educational experiences (Kohen-Vacs et al., 2016).

In this chapter, we describe our ongoing work to design, develop and deploy different software solutions to support collaborative seamless learning activities practiced across a variety of settings. We present our efforts to address the research question of how best to design systems and tools to support students during the implementation of collaborative seamless learning activities.

We therefore describe three learning activities that we designed, developed and deployed. In the next section of this chapter, we describe our approach, which enables researchers and teachers to consider the design of learning activities that are intended to be seamlessly practiced across contexts. Following this, we suggest an architecture that is inspired by our implementations and is intended to support such activities while focusing on interactions that can take place across contexts and settings. Our proposed architecture contains various types of modules and software components that are capable of supporting various modes of interactions, whenever and wherever required by students, and which can be socially organized in various settings. In this way, we show how the main features required to support collaborative seamless learning, such as flexibility, expansibility and reuse, are constructed in the proposed architecture. More specifically, we discuss Web and mobile technologies, and other components offering support for existing and new types of educational interactions to be designed and deployed. We also consider these exciting and emerging interactions in terms of the ways they interrelate within these activities. In particular, we discuss various types of interactions in terms of the interoperability features required in activities performed across different contexts and settings. Finally, we present our conclusions and describe directions for future work.

2 Towards Collaborative Seamless Learning Across Contexts

As mentioned previously, mobile seamless learning involves special features, in the sense that it can be practiced across contexts and in various settings. In this section, we will specify and elaborate on these types of activities, while emphasizing the richness of options opening the way for potential opportunities to implement innovative collaborative learning activities. In addition, we will highlight the challenges faced by researchers and teachers when considering a process that includes the design, development and deployment of these types of collaborative and seamless learning activities.

In Fig. 1, we illustrate a process that can be started by various types of actors or stakeholders, including researchers and/or teachers exploring functional requirements for educational activities to be practiced across contexts (Kohen-Vacs, 2016). In this sense, we argue that the process illustrated here is adapted to the nature of such activities, since it provides opportunities to consider, evaluate and evolve a set of interwoven specifications that can later be implemented as interrelated interactions to be exercised across contexts.

The initial step in the process illustrated above can be repeatedly evaluated, until stakeholders decide to transform the identified requirements into practical designs.

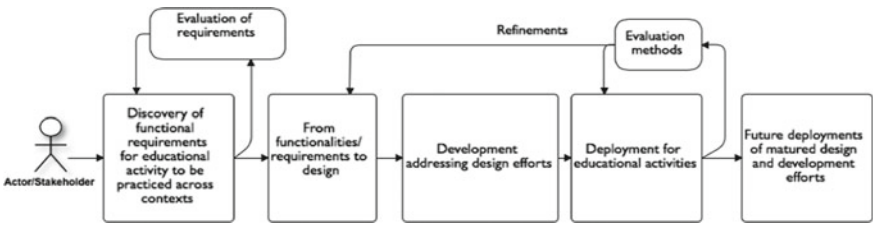

Fig. 1 Design and deployment efforts towards collaborative and seamless learning activities to be practiced across contexts

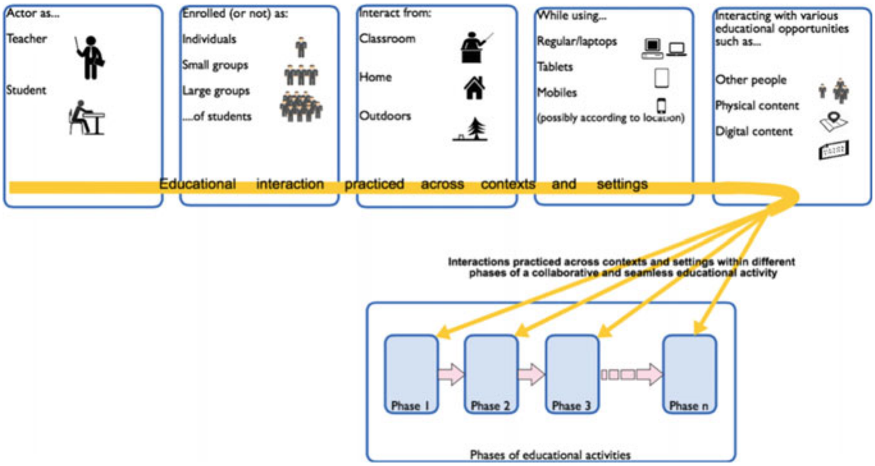

Fig. 2 Educational interactions executed within phases of collaborative and seamless activities

In the next step, these design efforts move into the developmental stage, followed by deployment through the implementation of educational activities. These two steps could also be evaluated using several iterations, for further refinement. Eventually, this process matures into design and development efforts that can be offered to researchers, teachers and students in future educational activities. In Fig. 2, we show the possible options for structuring and enacting collaborative and seamless learning through practices exercised by teachers and students, organized in various settings. In addition, these interactions could be conducted from several locations and supported by different types of technological devices and tools. Students could interact from anywhere at any time, with digital content stored in the cloud and deployed by their teachers as part of a pre-planned educational path. Alternatively, they could interact with objects that emerge during the enactment of these activities, which can be used as new and appealing educational opportunities (De Jong et al., 2010).

The figure above shows an educational activity involving various actors (stakeholders), including teachers and students, and illustrates how they participate in an orchestrated activity consisting of multiple phases. In addition, we demonstrate that their participation in each of these phases may involve interactions while enrolled in different social settings (individual and small/large groups). They may participate in this activity from several locations offering educational opportunities. During participation, they use various technological devices to support their educational interactions. Finally, it should be mentioned that teachers and students can interact during these activities with their peers, with physical content found in their location or with digital content accessible via their technological devices.

The practice of these educational activities has been extensively described by the research community, including by Spikol and Milrad (2008) and Zurita, Baloian and Frez (2014). In some cases, students have used technologies that aimed to facilitate interactions across contexts. Mobile and other Web tools have been exploited to make interactions more continuous and seamless, while aiming to provide a learning flow.

As described in our previous research work, we designed and deployed activities reflecting computer-supported collaborative learning (CSCL). These deployment efforts were implemented across contexts and settings, and required the design and development of a process fostering seamless learning (Kohen-Vacs, Ronen, Ben Aharon, & Milrad, 2011; Kohen-Vacs et al., 2016; Spikol & Milrad, 2008). In a previous research study, we consolidated and addressed the combination of CSCL and SL as collaborative seamless activities (CSL) activities (Kohen-Vacs, 2016).

The design and development process of CSL activities includes opportunities related to a learning process that is potentially rich in terms of its content and the type of interactions that can be practiced from real settings. These opportunities should be examined in the light of both the advantages they offer and the challenges involved. For example, the organizational aspects of CSL activities, including the temporal line of enactment, places of practice and social settings, present the designers of such activities with challenges that are recognized by the research and teaching communities. Furthermore, in some cases, these challenges discourage communities of practitioners from implementing such educational activities. In view of this, intensive efforts are currently being made to alleviate these challenges using technological tools that offer a convenient means for facilitated interactions. Equally important are the educational aspects that should be considered when adopting and implementing technologies for such activities. In general, the educational content should be adapted for digital use, in order to maximize its pedagogical potential. Consequently, we find that opportunities and challenges related to the deployment of CSL activities can be examined in the light of three main aspects drawn from MSL dimensions: the educational, organizational and technological aspects (Wong & Looi, 2011). We acknowledge these aspects and dimensions in the light of our research efforts exploring CSL activities, as discussed in our research aims in the introductory section.

In the next section, we present a sample of three activities we designed, developed and deployed with the aim of providing teachers and learners with CSL activities. These three activities are described, including their opportunities and challenges, since we later use them as exemplary cases resulting from the design approach proposed here. In a later section, we suggest an architecture based on this design that enables their deployment in real settings. We also show that these three activities share many similarities in terms of their educational aspects, administrative challenges and the technological means used to support teachers conducting these with their students.

In the next section, we present some of the efforts we have made to enable collaborative seamless learning across contexts and in various settings. The process of designing, developing and deploying mobile learning should be carried out while taking into consideration the different dimensions related to individual and social learning, as well as the geo-temporal aspects of the learning situation and the models of interaction (physical, virtual and a combination of both) (Muñoz-Cristóbal et al., 2015; Pea et al., 2011).

3 CSL Cases

As previously mentioned, this section presents three CSL activities that aim to provide a collaborative learning experience across settings with the support of various Web and mobile technologies. We describe and present another activity providing students with the opportunity to become familiar with the usability issues that can be found in their daily lives. We offer teachers and students the chance to participate in this activity as part of a collaborative learning experience carried out using various trajectories across different contexts (Kohen-Vacs et al., 2011). We then describe an activity developed in relation to the Learning Ecology through Science with Global Outcomes (LETS GO) project (Vogel, Kurti, Milrad, Johansson, & Müller, 2014).

Finally, we discuss an activity that aims to enhance educational experiences through the use of interactive videos supported by a Web environment called EDU.Tube, which operates on both regular and mobile devices (Kohen-Vacs et al., 2016).

3.1 Case 1: Usability Issues

This activity aims to familiarize students at the university level with usability topics, using authentic issues encountered on campus. This activity consists of five stages, beginning with an initial activity requiring the student to perform it outdoors using a mobile device. This activity also includes interactions that are exercised across contexts and in various settings, in a manner that requires design and development efforts to consider the MSL dimensions (Wong & Looi, 2011; Wong, Milrad, & Specht, 2015).

This activity includes a phase that aims to provide students with general information about the topic of usability. It also includes a subsequent phase performed outdoors in 10 groups of three to four students. In this stage, students are challenged to tour the campus and to identify usability problems of types identified by them in formal lessons. Students who spot such an issue can use a mobile device to take and submit a picture that represents it. The students are also required to submit a short description explaining the usability issue captured in the picture. In Fig. 3, we illustrate students interacting during the second phase while encountering a usability issue on campus.

The figure above shows two students participating in the course on usability issues, taking part in an activity conducted both indoors and outdoors in order to enable familiarization with these issues. More specifically, these students are pointing out a usability problem found within the outdoor environment of their campus and are taking a picture that includes a geo-tagging (GPS) location and a text explaining the nature of the usability problem. The next phases of this activity are intended to be performed at home via the Web and computers. In the second phase of the activity, members of each group select the best item identified by members of their own group. The third phase focuses on an analysis of the tagging: Each student is presented with four of the usability problems documented by other groups and is asked to select up to

Fig. 3 Students identify a usability issue located outdoors

three tags from a given list that best describe the problem. In the fourth phase, students vote on the most significant issues, as represented by the contributed pictures. In this phase, we aim to engage students through appealing interactions while requesting them to vote for the issue that was best tagged by the participants. The fifth and final phase includes a presentation of the results of the competition and a debriefing by the teacher, based on the information contributed by students throughout the activity. This activity relies on Web and mobile technologies to support the teacher's and students' interactions. We use the MoCoLeS system based on Google XFORMS to support mobile interactions, including their storage in a Web environment. In addition, we use the CeLS environment with related middleware to orchestrate the teacher's and students' interactions taking place throughout the interrelated phases of this CSL activity (Kohen-Vacs et al., 2011).

3.2 Case 2: LETS GO

LETS GO learning activities were deployed as part of an environmental science curriculum and were aimed at students at the K-12 level. In these activities, learners focused on exploring various environmental characteristics, including the quality of the soil and water (woodland ecology) in their neighbourhood. These activities usually include workshops aiming to enable the students to become familiarized with the specific subject matter and central concepts, through ideas associated with the inquiry and learning process (Vogel et al., 2014). The educational interactions carried out across contexts and settings in this activity are illustrated in Fig. 4.

In the figure, we illustrate the various requirements for this activity, including the mobility of students and teachers across the distributed environments offering educational opportunities. In addition, this figure shows the utilization of technologies supporting students' interactions, including the use of various devices communicating with the service-oriented systems responsible for handling users' posts. In particular, these posts deal with data collection and interaction with peers, as part of a collaborative and educational activity.

These activities usually comprised six to eight lessons over a period of five weeks, starting with an introduction to the inquiry process in which the basic concepts of the activity were introduced and students discussed the initial questions given to them about a specific topic (e.g. water quality). A particular LETS GO activity included learning interactions to be carried out across contexts and in various settings, in a

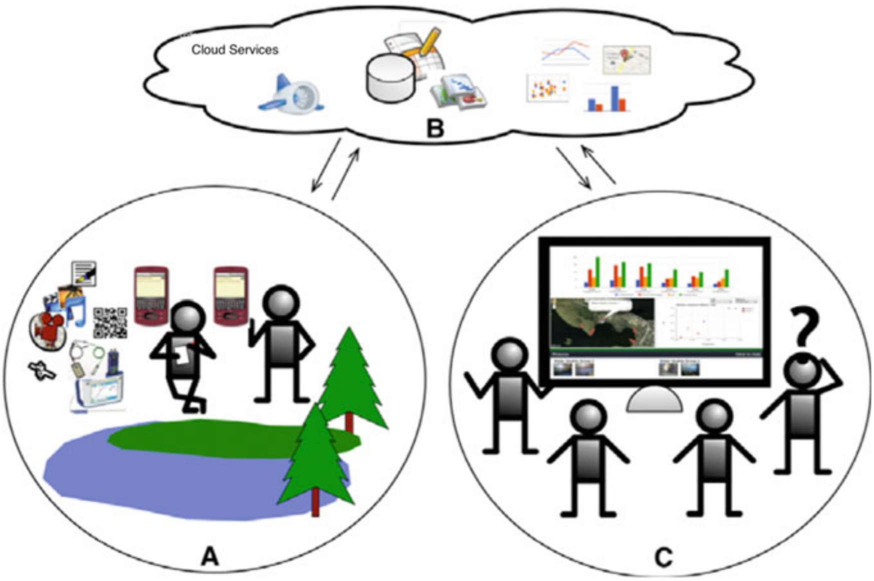

Fig. 4 Conceptualization of the different interactions in a LETS GO activity (Vogel et al., 2014)

manner that required design and development efforts to consider MSL dimensions (Wong & Looi, 2011; Wong et al., 2015).

This activity can be followed up by preparation for investigations and experiments to be conducted using different technologies (probes, data loggers, mobile applications for data collection in the classroom). Additionally, learners can conduct field experiments within the local environment and collect samples for laboratory analysis. Data collected using the mobile data collection tool included geo-tagged content and sensor data (usually pH, dissolved oxygen, temperature, conductivity, moisture, etc., depending on the type of activity). This learning activity usually ends with a discussion of the findings from the field and laboratory work, and an overall class discussion and reflection using the Web visualization tool, which tailors the different geo-tagged sensor data and digital content collected using the mobile data collection tool. In this case, we used XML and JSON to store and share the teacher's and students' interactions between mobile devices. A Moodle learning management system was used to support this activity.

3.3 Case 3: Interactive Videos

In this activity, we asked students attending computer science and programming courses at Bachelor's and Master's levels to track educational videos and convert them into interactive and rich media learning opportunities. This learning activity was designed for undergraduate students learning essential terms in the field of computer science. The design and development of this activity also required addressing various concerns reflected in MSLs (Wong & Looi, 2011; Wong et al., 2015).

The activity is technologically supported by the EDU.Tube authoring environment, which enables students to incorporate video clips found on YouTube with educational interactions. In addition, the activity includes other orchestrated interactions related to those of EDU.Tube that are supported by another environment called Collaborative e-Learning Structures (CeLS). This activity consists of four sequenced phases and starts by requiring students to look for videos with educational potential, which may assist with the teaching of concepts related to computer science and programming. Students are also required to author educational interactions and to incorporate these into scenes they have identified in videos, aiming to transform them into interactive and educational opportunities. In Fig. 5, we illustrate an educational interaction incorporated into a video, thus transforming it into an educational opportunity.

In the figure, we illustrate a student's interaction, occurring when the video reaches a predefined point in its timeline (see the left-hand side of the illustration). In this case, arrival at a predefined point triggers the appearance of an educational interaction, as illustrated on the right-hand side of the figure.

In the following phase, students are asked to assess seven interactive video clips, authored by their peers within the same study group. Students conduct their assessments using regular or mobile instances of EDU.Tube on their own devices of various types. In the next phase of the activity, students are required to select the three best

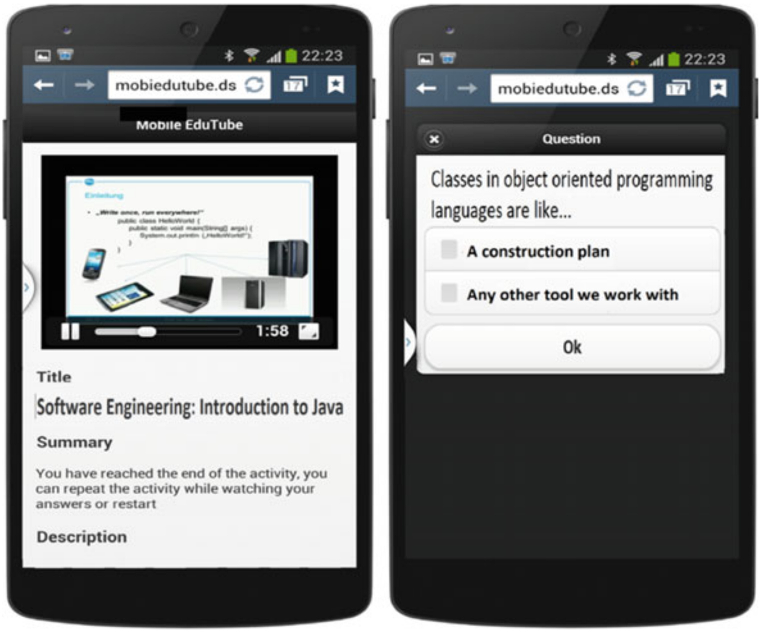

Fig. 5 Illustration of educational interaction involving topics in software engineering as experienced on a mobile device

videos authored by their peers and are required to support their selection with a text-based justification. The final phase of this activity takes place during a debriefing session in which teachers use CeLS and EDU.Tube to present selected (mostly voted on) videos to the students. Teachers also discuss the students' insights, as expressed by their fellow students during the peer assessments. Selected artefacts are used in the debriefing session as educational and attractive opportunities, recognized as pedagogical contributions by both the teachers and the students.

4 Mapping the Educational, Organizational and Technological Dimensions of the Described Cases

The design of CSL activities, as described in the cases mentioned above, includes various educational, administrative and technological requirements that need to be considered by researchers, teachers and developers during their deployment efforts. In particular, these considerations play a crucial role in the educational design of such activities, as well as in work focused on technological development that aims to alleviate administrative and pedagogical challenges.

As previously discussed, the educational, administrative and technological aspects of such activities are addressed through various MSL dimensions, as described in the list below (Wong & Looi, 2011; Wong et al., 2015):

- (MSL-1) Encompassing formal and informal learning
- (MSL-2) Encompassing personalized and social learning
- (MSL-3) Learning across time
- (MSL-4) Learning across locations
- (MSL-5) Ubiquitous access to learning resources
- (MSL-6) Encompassing physical and digital worlds
- (MSL-7) Combined use of multiple types of devices
- (MSL-8) Seamless switching between multiple learning tasks
- (MSL-9) Knowledge synthesis
- (MSL-10) Encompassing multiple pedagogical models

In the following paragraphs, we will target three of these dimensions that are most relevant to our research and deployment work. We focus on MSL-2 to address the social nature of the educational interactions, MSL-4 to reflect the nature of the educational process exercised across locations, and MSL-7 to examine the combined technological means required for interactions in the context of mobile learning. Table 1 illustrates various aspects of CSL and their application in terms of MSL dimensions.

In this table, we present the aim and goals for each case, including their educational, logistical and technological challenges. In addition, we show how these aims

Table 1 MSL dimensions reflected in CSL deployments

Dimensions mainly addressed	Case 1: Usability issues	Case 2: LETS GO	Case 3: Interactive videos
(MSL-2) Encompassing personalized and social learning	CeLS	Moodle	CeLS
(MSL-4) Learning across locations	Indoors and outdoors	Indoors and outdoors	Anywhere
(MSL-7) Combined use of multiple types of devices	MoCoLeS, CeLS Integrate CeLS and MoCoLeS to support the design and enactment of CSL activities to be performed outdoors using mobile devices, and indoors using stationary computers	Proprietary mobile client LETS GO, used with Moodle system Integration with external services to provide various services, including maps, visualizations, forms, spreadsheets and Flickr services	CeLS and mobile EDU.Tube Integration of two approaches to support the design and enactment of CSL activities enabling students to author and interact with educational video clips from anywhere, using stationary and mobile devices

and goals are achieved through technological implementations, including the use of Web and mobile technologies that are integrated and communicate with databases. The table illustrates various aspects that need to be considered in the deployment efforts for each of the CSL activities. These varied aspects represent opportunities and challenges that must be acknowledged or tackled during the design and deployment of these activities. In the next section, we propose an approach to iterative design that enables the gradual alleviation of the interrelated concerns that typically exist for such CSL activities.

5 The Proposed Approach to Designing CSL Activities

In this section, we propose a design process that offers an approach to addressing the various challenges that typically exist in CSL activities, including:

- Orchestrating educational tasks that reflect pedagogical approaches;
- Specifying educational tasks with social, temporal and location settings;
- Technological support for the actual interactions taking place throughout the phases of the designed activities;
- Providing an effective means for the evaluation of CSL activities.

As shown in Table 1, these opportunities and challenges align with MSL dimensions (focusing primarily on MSLs 2, 4 and 7). Specifically, the first and second points relate to the elicitation of requirements for educational tasks reflecting various educational aims. The second point is related to the organizational aspects that need to be set for these educational tasks; as stated in MSL-2, these reflect the social settings of educational processes. The next point addresses the ubiquitous nature of CSL activities, as reflected in MSL-4. Finally, we address the technological means required to support these activities (the nature of the devices mentioned in MSL-7). The last point addresses aspects related to the evaluation of such CSL activities. As mentioned in the introduction, these challenges in terms of educational design have been addressed by several different researchers, including Wong and Looi (2011) and Milrad et al. (2013). Kohen-Vacs (2016) proposes a design approach adapted from research efforts carried out by Ravenscroft, Schmidt, Cook, and Bradley (2012). These ideas are illustrated in Fig. 6.

In Fig. 6, we illustrate our proposal for a design process that spans three iterations. In the first iteration, we suggest considering and carrying out various design tasks, including:

- Prioritization of aspects reflected in the different MSL dimensions, concerning the goals and challenges of the activities. This prioritization aims to enable the design of activities for multiple purposes while conceptualizing their educational, organizational and technological aspects.
- An exploratory phase that examines the experiences and constraints related to different aspects of the CSL activity.

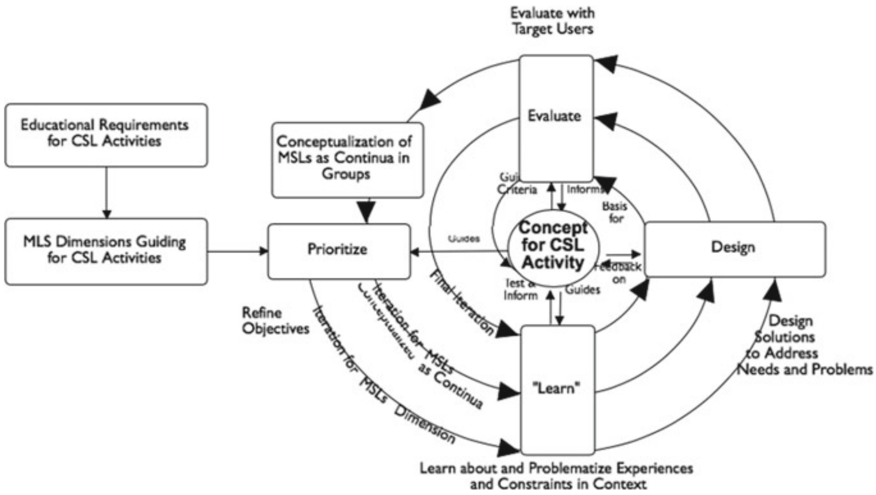

Fig. 6 Spiral iterations included in the mature design process. Adapted from Ravenscroft et al., 2012)

- A practical design process that aims to provide potential solutions linked to implementations of CSL activities.
- An evaluation phase that addresses the ongoing design process and focuses on how the diverse MSL dimensions were conceptualized in the previous design process.

These tasks are repeated in the next iteration, while conceptualizing MSLs in the same continua (Milrad et al., 2013). The last iteration includes a final session that aims to assess the challenges arising from previous iterations requiring additional adjustments. In the next phase, the final design is evaluated and proposed as a mature concept of a CSL activity, to be offered for adaptation and reuse in the future. In this section, we propose a process that offers researchers and teachers the opportunity to conceptualize and design CSL activities while taking into consideration their educational and administrative requirements. In addition, this design process offers an opportunity to identify the technological aspects that need to be developed and deployed in order to provide support for such activities. The spiral approach proposed by Kohen-Vacs (2016) was inspired by and accordingly shares characteristics with the interventions used in design-based research (Anderson & Shattuck, 2012; Brown, 1992; Collins, 1992). This approach also aims to provide an iterative process focusing on repeated interventions, testing and improvement, towards the best design of mature concepts, and thus better serving educational processes.

In the next section, we present our proposal for a software architecture that offers support for CSL activities, including the range of aspects reflected in MSL dimensions.

6 From Design to Technological Deployment of CSL Activities

In the previous sections, we illustrated various aspects that should be considered during the implementations of CSL activities, and discussed both the educational and administrative aspects related to these kinds of learning interactions. Furthermore, these administrative aspects could be examined as organizational challenges which need to be addressed in order to implement such activities. Over the past decade, numerous research efforts have dealt with some of these challenges, referring to them as orchestration challenges for collaborative learning activities (Håklev, Faucon, Hadzilacos, & Dillenbourg, 2017; Roschelle, Dimitriadis, & Hoppe, 2013). As mentioned above, CSL activities intensify these kinds of challenges in activities such as those presented in the previous section, including the collaborative aspects. Consequently, we find that these challenges could be supported by a set of interrelated services included in a service-oriented architecture.

In the previous subsection, we elaborated on the design of mature CSL activities, illustrating how the dimensions are conceptualized through an iterative design-based process. Within this process, we suggest examining the various aspects of CSL activities as reflected by the MSL dimensions. We also examine how these aspects combine towards the establishment of more mature concepts for CSL activities. Such an architectural approach is well-known in the context of service orchestration and can potentially be implemented for the orchestration of educational interactions (Mayer, Schroeder, & Koch, 2008). For example, in the proposed design process, we consider the requirements for supporting educational interactions in terms of both mobile and more traditional learning. This variety of interactions may require the use of services supporting different types of interactions, e.g. synchronous or asynchronous interactions.

In Fig. 7, we illustrate our proposal for a general architecture to support the implementation of CSL activities. In this illustration, we do not intend to present an architecture for an abstract concept. Instead, this presentation aims to suggest an architecture which is close to implementation.

The illustrated architecture is based on a service-oriented approach and includes the integration of components that are intended to offer different functionalities, resulting from the outcomes of the design process. This representation of the architecture is designed to be as close as possible to an implementation, while offering an applicable approach aligned to the practice of CSL activities. This architectural approach allows implementers to choose from a set of services, but does not require the deployment of all of them. In addition, the nature of this architecture allows the possibility of implementing new cases while easily introducing any new services required. These new services could serve and be reused in additional cases supported by this architecture.

For interactions, such as those required for the LETS GO project or the activity focusing on usability issues, an XForm component was adopted and integrated, in order to support students' interactions across locations. In addition, teachers and stu-

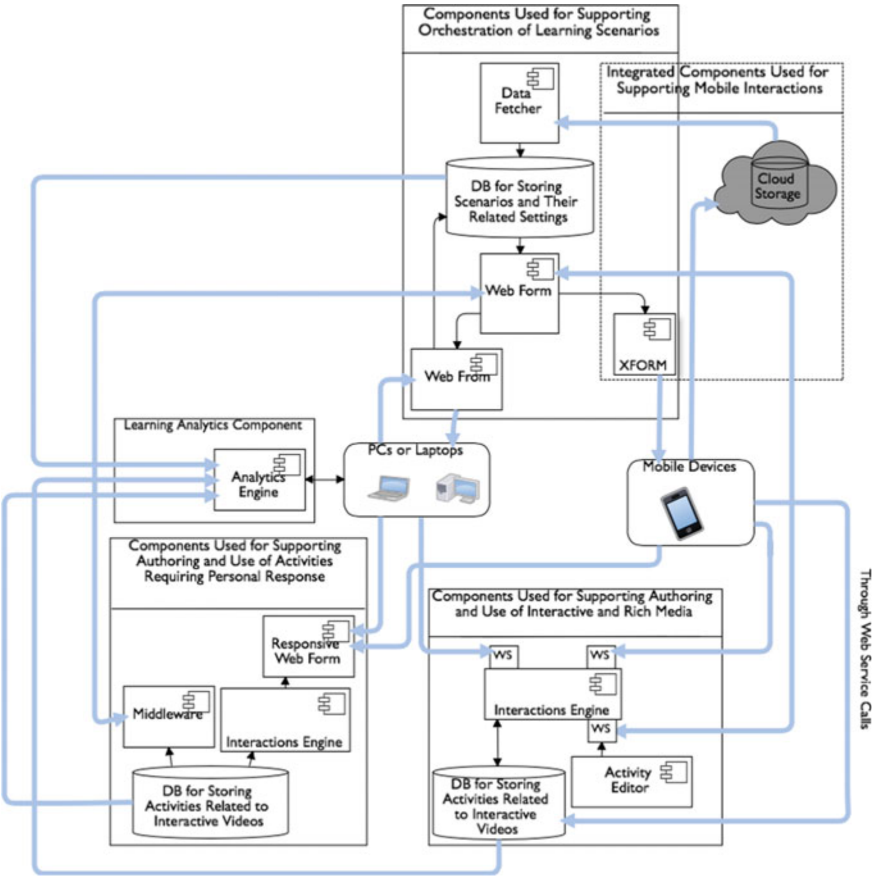

Fig. 7 Overview of the proposed architecture

dents can interact in various modes in these activities, while using services supporting personal responses across contexts. Activities consisting of rich and interactive media, such as that dealing with interactive videos, may be supported by components enabling teachers and students to experience such content on mobile or personal computers. As illustrated in Fig. 7, we consider the deployment of micro-services, including one responsible for handling interactions with rich media. This micro-service uses its own database to store its own interactions; however, it also uses an additional database that is responsible for handling the additional data needed to use this service throughout orchestrated activities. As shown in the figure, the micro-services deployed in this architecture are interconnected in a way that allows their use during the orchestration of a certain activity. In addition, these services could be reused in various other activities that use different settings for orchestrations requiring the same kind of technological support. It should be mentioned that our approach is aligned with other research efforts involving activities based on an architecture providing various options for the contextualization of micro-services offering rich options and flexibility, in terms of support for various types of educational content and various ways to mediate this across technologies (Sharples, 2015; Sotsenko, Zbick, Jansen, & Milrad, 2016). Finally, the proposed architecture includes an analytical service that is interconnected with the orchestration components, including the databases corresponding to the various reusable micro-services and the database storing the CSL scenarios. This integration of the analytical service aims to allow future analysis, based on the interactions offered and supported by different types of micro-services for users who are organized in various social settings. Eventually, this feature will allow a better understanding of the educational processes practiced in CSLs and will enable possible supportive interventions (Prieto, Sharma, Dillenbourg, & Jesús, 2016).

We suggest that this type of architectural approach can offer technological support for the implementation of a mature concept for a CSL activity. Technological support for the proposed design approach relies on integration of the technological components required to support the various aspects of CSL activities. In addition, the incorporation of these components into the architecture was achieved while emphasizing the generation, sharing and reuse of content, based on the aspects typically required by teachers when designing educational activities for real settings. It should be mentioned that this architecture provides rich possibilities for reuse at two levels: the educational content level (learning materials) and the technological level represented by the implemented services. The realization of this sharing and reuse of generated content is addressed in Fig. 3 by including middleware and Web services. In addition, this architecture provides rich possibilities for reusing the components for newly introduced services, as discussed above.

7 Summary and Conclusions

In this chapter, we present an ongoing effort to propose new approaches for designing, developing and deploying CSL activities. This effort is based on investigations carried out over the past decade. Here, we report a sample of these efforts applied to three activities, designed with a focus on collaborative and seamless learning experiences. In particular, we describe activities enabling teachers and students to benefit from collaborative and seamless learning experiences within various domains, including usability issues, environmental studies and computer science.

This study includes one learning activity connected to the LETS GO project, which involves environmental studies; another activity that allows students to learn about usability issues in authentic settings; and an activity focusing on the authoring and exploitation of new educational opportunities through interactive videos. We also describe the interactions and technologies used to support various use case scenarios, including indoor and outdoor interactions involving data collected from real settings and later reused as new educational opportunities. In addition, we allow the teacher and students to interact with rich media from anywhere and at any time. We then summarize our discovery and analysis efforts focused on aspects of CSL activities, while reflecting on them in terms of the educational, logistical and technological requirements inherent in the MSL dimensions. In this sense, we argue that the MSL dimensions can be exploited as a convenient means of analysing and then designing and deploying such activities. Our proposal recognizes the different MSLs and considers their use throughout the design, development and deployment of CSL activities. We suggest this as a process that can potentially provide researchers, designers or teachers with new opportunities to evaluate their educational efforts in a comprehensive way. In the subsequent steps of the design, we propose an iterative process consisting of several steps, including prioritization of the aspects related to CSL activities, which is followed by another exploratory phase addressing the experiences with and constraints on such efforts. In the subsequent steps, the actual design is produced, and this is followed by an additional evaluation phase that may lead to additional cycles of refinement. We believe that our proposal can offer a convenient and robust approach for researchers, teachers and other practitioners seeking ways to achieve, implement and reuse mature designs for CSL activities. Furthermore, we believe that there is a strong relationship between mature designs for CSL activities and their novel implementations. We argue that the exercise of best practice during the design process opens the way to optimizing the practical potentials of such activities while being technologically implemented.

We also find that this approach aligns with our aims, as presented in our research question regarding how best to design systems and tools to support students during the enactment of collaborative seamless learning. We propose an approach that allows an analysis of the requirements related to the actors conducting and participating in such activities. We also consider the educational, administrative and technological requirements relevant to the enactment of these types of educational enactments. Furthermore, we propose the utilization of MSL dimensions to facilitate identification of the various types of affordances and challenges that need to be tackled in the deployment of these activities, and propose the use of these dimensions in a comprehensive way to iteratively design and develop such activities. These efforts encompass both the educational and technological aspects required to support them across contexts and settings. In particular, our approach considers the various stakeholders typically involved in such deployment efforts, and we offer a deployment framework involving the various specialists with the corresponding tools enabling them to conveniently exercise their professional practices throughout the design and development of CSL activities. Furthermore, the exploration and development aspects of our approach acknowledge and encompass the varied expertise of the different stakeholders, addressing interrelated framework for deployment. These efforts were consolidated into a deployed activity consisting of micro-services that offer the capability to address educational requirements in terms of interactive content and the corresponding technology required to support it. We also offer these efforts for reuse and implementation in other educational activities, possibly orchestrated across other settings.

In summary, we suggest the implementation of a novel architecture aimed at CSL activities reflecting the proposed design approach. This architecture is service-oriented and is flexible enough to enable expansion and the introduction of new services to support new functionalities. These services may be required by new activities or could be reused in the case of new activities requiring the same services as those previously implemented. We demonstrate that the suggested architecture enables the introduction, exploitation and reuse of its components containing various services. In terms of the actual educational data supported by such services, we find that this interrelated set of services supports the introduction, interaction and reuse of existing educational content. In future work, we will further refine our approach to CSL activities, while considering those with new educational and innovative functional requirements. In addition, we will maintain and keep up to date our architectural approach so that it better supports innovations emerging from future CSL activities.

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