A Design and Development Approach for Deploying Web and Mobile Applications to Support Collaborative Seamless Learning Activities
Abstract

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The main aim of the research was to investigate how best to design tools and systems to support students during the enactment of collaborative seamless learning activities, and to provide teachers with artifacts to design and assess those. Special emphasis has been given to the exploration of approaches that enhance the flow, reusability and sharing of learner-generated content across different learning activities. Several studies were conducted in order to validate and assess these ideas and concepts. Various data collection methods were used to gather data from different stakeholders during the deployment of the different CSL activities. The outcomes were processed and analyzed resulting in a set of recommendations concerning the design, development and deployment of web and mobile applications to support collaborative seamless learning. A software architecture including various web and mobile integrated components used to support innovative CSL activities is also proposed.
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”He who cares for days, plants wheat;

He who cares for years, plants trees;

He who cares for generations, educates people.”

Janusz Korczak (1878-1942)

Dedicated to my beloved grandfather, David Vacs
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Acknowledgments

There have been many exciting moments and challenges experienced along the journey that led me to write my doctoral thesis. A few years ago my six-year-old son asked me a seemingly innocent question about my work, and what I was doing it for. Although I intended to provide him with a simplified response, I realized the importance of his question, and that a full response required serious contemplation. I began my journey through recognizing the crucial role of education and while considering the technological advancements that could enhance learning, with a belief that the role, practices and type of tasks related to teacher-student relations is expected to advance and lead in new directions. Korczak often emphasizes how crucial education is for many aspects of societies. I saw that the scope and growth of education could be advanced by technology. New opportunities open up almost every day, and all one needs is to explore and exploit them in order to enhance education by technological advancements.

Happily, many people see and understand these opportunities, and thus I was able to share diverse experiences with many people from different places. I would like to express my gratitude to them for their support and friendship along the way.

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1. Introduction

In this thesis, I address some of the challenges related to the design, development, and deployment of web and mobile technologies, tools, and systems to support Collaborative Seamless Learning (CSL) (Wong, 2012; Milrad et al., 2013) activities practiced across a variety of learning contexts. My research efforts include the elicitation of requirements as well as the design of a number of web and mobile tools to support CSL activities.

The main aim of the research I carried out over the last 5 years was to investigate how best to design tools to support students during collaborative seamless learning activities and how to provide teachers with artifacts to design and assess these activities. Special emphasis was given to the exploration of approaches that enhance the flow, reusability, and sharing of learners' generated content across different learning activities.

In order to set the context of my research and to provide a rationale for my efforts, this chapter provides a brief overview of topics related to various aspects of this research. In this manner, I address developments and uses of Information and Communication Technologies (ICT) aimed for supporting novel educational activities. Section 1.1 covers some of these aspects related to the adoption of stationary as well as mobile technologies that are used in educational settings by teachers, students, and researchers. Special emphasis is given to mobile devices and their ability to support collaborative seamless learning (CLS) activities. Section 1.2 provides a motivation for the direction of my research and elaborates also on its scope. In section 1.3, I describe the aims of my research in order to provide the reader with a detailed overview. Section 1.4 concludes the chapter, where I provide a synopsis of the thesis structure and its content.

1.1. Background

ICT offers a wide range of affordances for supporting humans in different domains that rely on information processing and computer-mediated communication. The term ICT covers many interrelated subjects, and includes computational and communicational aspects. It also addresses diverse types of technologies at different levels (Sarkar, 2012). For example, ICT may address applications supported by stationary computers as well as on mobile devices. These applications and technologies can be used by individuals or and organizations to improve accessibility and interactivity to information aimed to
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support people's daily experiences and routines. The latest generation allows people to carry out such activities from any place with connectivity at any time.

Mobile devices nowadays, with their computational and communicational abilities, offer a convenient way to support different kinds of interactions across a variety of physical locations. Over the last decade, the penetration of mobile technologies among different sectors of society has increased significantly (Goggin, 2012). The adoption of these technologies is reflected in the number of smart mobile users in the world, estimated at 1.75 billion (Emarketer, 2015). A recent Nielsen report examines how mobile technologies are used, and it reveals that mobile devices have started to penetrate into the educational sector (Nielsen, 2015). Mobile devices are now used to support different types of tasks that can be conducted in a wide range of learning activities. Computer-based tools in the field of education have been known for almost four decades, while the advantages of mobile technologies in education have been acknowledged for more than a decade (Sharples et al., 2014). In this sense, ICT is used to support different activities and processes that together constitute a field known as Technology Enhanced Learning (TEL) (Balacheff et al., 2009).

TEL environments are used by teachers and students to support various educational practices. In many cases, these technologies are utilized to support advance educational activities that require teachers and students to interact in various complex modes. TEL solutions are used by teachers and students seeking better and more efficient ways to access and interact with various types of learning materials and educational opportunities, in virtual as well as in physical locations (Buzzetto-More, 2014).

Over the past decade, educational scenarios supported by mobile technologies have been constantly designed, deployed and explored. Mobile technologies allow teachers to exploit educational opportunities located beyond the traditional boundaries of their classrooms. Accordingly, they may organize educational activities conducted in places like school yards, parks or museums (Alexander, 2004; Milrad et al., 2013). These activities allow students to explore objects located in their vicinity, such as to investigate natural phenomena or landmarks. These efforts may include interaction supported by mobile devices utilized for taking pictures, notes or capturing GPS coordinates of the location of a particular object. In addition, students can use their mobiles to access the web in order to seek for information related to the object under exploration. They can also use these devices to consult or elaborate their ideas with peers without having to meet. Material thus learned and collected can then be brought into the classroom via stationary devices as well, for a debriefing session conducted in the classroom.

The adoption of mobile technologies among teachers and students correlates with the wide embrace of mobile technologies by the general population across different sectors and for different daily tasks (Kobus, 2013; Purcell et al., 2013). Recent research indicates that mobile devices have been widely adopted also by pupils in primary school (Gikas & Grant, 2013; Khaddage et al., 2014). This
aspect is well addressed in one of the latest New Media Consortium (NMC) Horizon reports, which mentions that modern educational approaches supported by mobile technologies are expected to become common practice among a wide number of educational institutions (Johnson et al., 2014). In addition, the research addresses the need for developing technological support for these new types of educational and social interactions. Such support will enable teachers and students to carry out their tasks synchronically and a-synchronously, interacting from different physical or virtual locations, and in different social settings (Gikas & Grant, 2013; Sharples et al., 2010). Designing and implementing such pedagogical activities, as well as the technological infrastructure and software tools to support them are challenging tasks that need to be explored systematically. This exploration is the core of my dissertation. In the next subsection, I will introduce the motivation and scope of my research.

1.2. Motivation and Scope

As mentioned earlier, my research deals with exploring the affordances of web and mobile technologies tools addressed during the design and deployment of TEL environments. Specifically, I examine TEL environments aimed to support CLS activities. In addition, my research explores ways to improve the design of TEL environments, enabling richer modes of interaction to provide a better seamless learning experience (Huang et al., 2014). These efforts involve various stakeholders seeking for better technological means to support collaborative learning across a variety of contexts.

Collaborative learning (CL) represents a pedagogical approach that involves groups of students working together on solving different educational tasks. This approach existed and has been successfully implemented by teachers before the emergence of e-Learning (Gamson, 1994; Salomon, 2000). Many teachers found it hard to carry out such activities, partly due to the pedagogical and logistical challenges associated with them. The introduction of ICT to the classroom in the 1990s revived this approach and made it easier for teacher and student to use it. This approach that uses ICT to support CL is known as Computer Supported Collaborative Learning (CSCL) (Kollar et al., 2006). CSCL is an approach wherein educational interactions are conducted while relying on the support provided by computers, mobile devices and network connectivity (e.g. Internet). The topics of CL and CSCL are extensively covered in the next chapter of this thesis.

Later advances in the field of TEL support teachers and students in mobile learning during CSCL activities (Zurita & Nussbaum, 2007). The mobile devices are used by teachers and students while they interact across different
learning contexts and along different phases of such of activities. I have identified several challenges concerning the TEL solutions used by teachers and students in CSCL activities. In my work I consider technological ways to engage in various pedagogical aspects of CSCL, including learning styles, educational approaches and didactical perspectives (as addressed in previous efforts by Sollervall et al., 2012; Wong, 2012). In addition, I consider administrative and logistical aspects related to the educational process that include students' social organization as well as timeslots and locations in which learning activities can be conducted. Finally, I consider modes of interactions in which teachers and students exchange data or information towards synthesizing new knowledge.

Another set of challenges concerns the methodology to be used for eliciting the requirements for deploying technologies used to support educational activities. My study suggests that TEL requirements could be gathered using tried and tested general approaches used also for other fields that deal with technological design and deployment (Alexander & Beus-Dukic, 2009). This process first identifies the stakeholders and their goals in terms of technology as well as pedagogy. The next phase is to find use-case scenarios that reflect the mentioned goals. These use-cases are analyzed and applied in the development of software solutions that support the design, orchestration and practice of collaborative educational activities, that is, regardless of the relative time and location of the collaborators. Lastly, the assessment and evaluation of the process relies on blended methods of data collection both quantitative and qualitative.

1.3. Research aims

The research efforts presented in this thesis were carried out at the Center for Learning and Knowledge Technologies (CeLeKT) at Linnaeus University, Sweden and at the Department of Instructional Technologies at the Holon Institute of Technology (HIT), Israel. During the last five years, I have been actively involved in research activities motivated by the authentic need expressed by teachers and students for alternative approaches to ICT-supported learning. In this context, the main research question that guides this thesis can be formulated as follows:

How to best design systems and tools to support students during the enactment of collaborative seamless learning activities and to provide teachers with artifacts to design and assess those?
In particular, the research I have carried out aims to:

- Explore the elicitation of requirements to be used for guiding design, development and deployment of innovative TEL environment, systems and tools exploited for design, enactment and evaluation of CSL activities;
- Improve existing TEL solutions used to support design and enactment of CSL activities;
- Optimize the integration of different TEL solutions enable better data flow and reuse of educational content along different phases of a learning activity;
- Support the flow of learning activities practiced across contexts and supported by several tools and environments (Giemza et al., 2007; Hoppe, 2015);
- Assess interrelated technological and pedagogical efforts practiced for such CSL activities.

The results and outcomes of these efforts are expected to generate a set of insights and recommendations to be proposed to other researchers and educational practitioners. These recommendations emphasize the following aspects:

- Elicitation of requirements for deployment of web and mobile tools aimed to be used in phases of CSCL activities
- Incorporation of innovative web and mobile tools to be combined with existing ones and used in order to support new types of educational interactions along these activities
- Orchestration of educational tasks empowered with dataflow that supports sharing and reusing of content generated by teachers and students along the different phases of CSL
- Assessment of the mentioned efforts

The realization of these recommendations will be illustrated in various cases supported by several web and mobile tools designed and deployed as part of my efforts. The identity and purpose of these tools as well as their implementation in different educational settings and activities are described later in several chapters of this thesis.
1.4. Overview of Thesis Structure

In this subsection, I present the structure of my thesis, the content of the different chapters and the interrelation between the various topics that have been explored. As mentioned earlier, this chapter commences with a brief presentation of the evolution of ICT technologies exploited for educational purposes. It then continues with additional sections concerning the scope and aim of this research. The rest of the thesis is organized and structured as follows. Chapter II offers a theoretical background describing the emergence and evolution of TEL environments. Specifically, I describe their evolutions made from CSCL to mobile CSCL and then to collaborative seamless learning. I then continue with other sections addressing various aspects of mobile technologies and their implementation during CSL activities. Chapter III provides a description of my research approach. It starts with a further elaboration of the research needs based on the motivations described in Section I, followed by a detailed description of research aim and questions. I then provide a description of methods used during my exploration efforts. Chapter IV offers a meta-level description of the different cases performed as part of my research efforts. In addition, I provide an abstracted overview of each of the attached scientific publications that are part of this thesis. Chapter V presents the results of the research conducted for this thesis. This is followed by another subsection analyzing and discussing the results. Chapter VI concludes this thesis with a summary of the results, the contributions, limitations and possible directions for future development and lines of research within this particular field.
Figure 1.1 depicts a graphical representation of the structure of the thesis and its interconnections.
2. Theoretical Perspectives

In this chapter, I discuss various theoretical aspects that are at the core of my research. I begin with a subsection analyzing collaborative learning (CL) and its affordances while being supported by ICT. I then elaborate on different ways in which CL activities can be carried out in a variety of settings while using ICT to offer more integrated and seamless educational experiences. In the next sections, I discuss how the field of mobile learning has evolved over the last 15 years while considering aspects related to collaborative seamless learning. I proceed by describing those aspects and challenges related to the orchestration of such collaborative educational activities conducted across multiple contexts. Finally, I conclude and summarize the main ideas presented in this chapter.

2.1. From CSCL to Mobile CSCL

CL is a pedagogical approach that covers a wide scope of educational practices involving people exercising joint intellectual efforts (Smith & MacGregor, 1992). In such situations, two or more persons are involved in a learning process aiming to learn together (Dillenbourg, 1999). Educational practices related to CL have been known for several decades and have emerged from earlier theoretical perspectives guided by the ideas of social constructivism. In this context, Piaget suggested that learning occurs through a process of accommodation and assimilation conducted by individuals aiming to construct new knowledge (Piaget, 1972). In such a process, individuals develop their outlook and rethink what was misunderstood, as well as to better evaluate existing and new perceptions (Bodner, 1986; Kanselaar, 2002). CL is also profoundly related to ideas and a theoretical perspective developed by Vygotsky. His concept of the "Zone of Proximal Development" (ZPD) (Vygotsky, 1978) addresses differences between what a learner may achieve without assistance compared to his/her potential achievements with the support of a peer. The notion of ZPD has been addressed in previous research efforts aiming to explore better ways to practice CL activities (Tongchai, 2005). Cunningham & Duffy (1996) addressed learning processes in relation to constructivism. Specifically, they addressed learning as an active process related to the construction of knowledge rather than just knowledge transfer. In addition they referred to learning as a process aiming to support that construction rather than communicating knowledge (Cunningham & Duffy,
The design of many CL activities takes into considerations these aspects of constructivism.

The design of such activities could be conveniently supported by innovative ICT technologies relying on powerful computational and communicational abilities. This type of technological support facilitates the design and enactment of educational activities to be carried out in various social settings. In addition, these activities could be practiced in various places and situations (Johnson & Johnson, 1999; Wood & O’Malley, 1996).

CL activities supported by ICT are traditionally called Computer Supported Collaborative Learning (CSCL) (Roschelle & Teasley, 1995; Salomon, 1992). Over the past two decades, the field of CSCL has experienced major advances in terms of different aspects concerning the interplay between pedagogy and technology. Practically, emerging ICT technologies offer new ways to facilitate the design and deployment of collaborative learning activities. Some of my previous research addressed novel ways of providing teachers with opportunities to model, enact, share and reuse online CL activities (Ronen et al., 2006; Ronen and Kohen-Vacs, 2010). Those research efforts served as a point of departure for addressing the design of web and mobile tools to support students during the enactment of collaborative seamless learning activities.

Nowadays, mobile devices are increasingly used to support CSCL activities. These tools are used to support such activities performed in various settings consisting of different types of pedagogical approaches that can be practiced across locations in various types of social settings. Over the past decade, such activities have become associated with the notion of seamless learning that aims to emphasize the bridging of learning practiced across a variety of educational settings (Chan et al., 2006). Milrad et al., (2013) addressed possible approaches for the design of future technologically enhanced learning activities that can support seamless learning. They mentioned students' options to rapidly switch between educational scenarios while using their mobile devices as mediators. In such situations, students are able to maintain the flow of learning practiced during their interaction conducted across different settings and supported by various technologies. Specifically, in such situations students organized in different social settings may interact in different modes while being in different locations and contexts. Cases that reflect CL situations practiced across these conditions are referred in this research as Collaborative Seamless Learning (CSL).

Previous research has addressed cases and various aspects of CSL activities. For example, Zurita & Nussbaum (2007) present mobile affordances to support efficient communication conducted between groups. So et al., (2012) deal with several considerations addressing new modes of interactions that could be practiced during CL activities conducted across locations while being technologically supported. Quay and Seaman (2013) address aspects of knowledge development and social skills acquired outside of the classroom. These efforts represent different attempts to explore ways to improve support
Over the past decade, mobile technologies continued to evolve and their use and adoption in the educational sector has increased. This growing adoption of mobile technologies can be examined and analyzed through an approach known as the Hype Cycle diagram (Fenn, 2007). The Gartner group developed this general approach, aimed to examine different phases related to the assimilation of emerging technologies used for various purposes. This approach can also be used to analyze and understand technology’s relevance and its roles for different domains, including education. The Hype Cycle diagram is used to illustrate this approach, presenting a typical pattern that describes the progression of emerging technologies through various phases. It commences with a phase referred to as a technology trigger that represents technological breakthrough. The next phase is known as the peak of inflated expectations, and it represents early publicity that results in success stories possibly accompanied by scores of failures. The third phase is called the trough of disillusionment that implies certain levels of dissatisfaction following overinflated expectations of early adopters of the technology (Frohberg et al., 2009). The next phase, the slope of enlightenment, reflects a better understanding of the applicability, risks and possible benefits related to the technology. In the final phase, the diagram describes an entry to the plateau of productivity that represents the full maturity of the technology.

Recent research carried out by Laru (2012) provides an analysis of mobile learning relying on the different phases presented in the Hype Cycle diagram.

2.2. The Evolution of Mobile Technologies for Supporting Education

In the previous sub-section, I presented the core issues related to my dissertation that focus on CSL. In the light of these efforts, I discussed some of the challenges associated with the design and deployment of CSL activities carried out across a variety of contexts and supported by mobile technologies (Gikas & Grant, 2013). In this section, I discuss how the latest developments and evolutions in mobile technologies can be used to support new approaches and technical solutions aiming to cope with the mentioned challenges.

The potential of mobile technologies to support educational activities have been explored for more than four decades. During the early 1970s, there were initial attempts to conceptualize the implementation of mobile technologies for supporting education. Specifically, the Xerox Learning Research Group (LRG) conceived of a device called Dynabook that was supposed to be enabled with communication abilities to be used for retrieving information (Goldberg, 1979; Kay, 1972). A decade later, there were some attempts to use hand-held devices for educational purposes mainly for supporting English teaching in classrooms (Kukulska-Hulme et al., 2009). In the mid-1990s, a broader approach for mobile learning was explored and put into practice in several European projects (Kukulska-Hulme et al., 2009). These efforts were exercised in the framework of various projects including HandLeR established for exploring concepts related to mobile and contextual learning practiced outside the classroom (Sharples, 2000; Sharples, Corlett & Westmancott, 2002). As mentioned, this project addressed general requirements that shaped later developments used to support mobile learning. These requirements addressed portability, adaptability and availability of mobile devices used for educational purposes. In addition, these requirements also considered the unobtrusiveness and usefulness of such devices. A few years later, the MOBILElearn project was introduced, aimed to facilitate ubiquitous access to information and content management for knowledge workers (Kukulska-Hulme et al., 2009; Zaharieva & Klas, 2004). These development efforts aimed to support mobile interactions related to registration, messaging and management of content required by workers (Da Bormida et al., 2003).
Over the past decade, mobile technologies continued to evolve and their use and adoption in the educational sector has increased. This growing adoption of mobile technologies can be examined and analyzed through an approach known as the Hype Cycle diagram (Fenn, 2007). The Gartner group developed this general approach, aimed to examine different phases related to the assimilation of emerging technologies used for various purposes. This approach can also be used to analyze and understand technology's relevance and its roles for different domains, including education. The Hype Cycle diagram is used to illustrate this approach, presenting a typical pattern that describes the progression of emerging technologies through various phases. It commences with a phase referred to as a technology trigger that represents technological breakthrough. The next phase is known as the peak of inflated expectations, and it represents early publicity that result in success stories possibly accompanied by scores of failures. The third phase is called trough of disillusionment that implies certain levels of dissatisfaction following overinflated expectations of early adopters of the technology (Frohberg et al., 2009). The next phase, the slope of enlightenment, reflects a better understanding of the applicability, risks and possible benefits related to the technology. In the final phase, the diagram describes an entry to the plateau of productivity that represents the full maturity of the technology.

Recent research carried out by Laru (2012) provides an analysis of mobile learning relying on the different phases presented in the Hype Cycle diagram.
Figure 2.1 below illustrates Laru's (2012) approach for categorizing and analyzing research dealing with topics related to the evolution of mobile technologies used for supporting education. His approach is illustrated in the Hype Cycle diagram.

![Gartner's Hype Cycle adapted to examine cases related to mobile learning](adapted from Laru, 2012)

The figure above illustrates Laru's approach to several cases presented in his doctoral thesis (marked by black dots). The examined cases were associated with the different phases of mobile learning, starting with two cases, one located in the technology trigger and the other in the peak of inflated expectations. These cases are related to initial R&D efforts to create and support the first generation of Personal Digital Assistants (PDAs) (Ogata & Yano, 2003; Rieger & Gay, 1997; Zurita et al., 2001). The next two cases (third and fourth cases) are associated with the phase called slope of enlightenment. The third case addresses the implementation of mobile computing and wireless internet exploited for educational purposes (Roschelle and Pea, 2002). The fourth case
reflects the actual age of mobile learning, enabling teachers and students with more affordable and better computational and communicational services exploited for learning purposes (Ally & Tsinakos, 2014; Glisic & Lorenzo, 2009; Norris & Soloway, 2011; de Waard, 2014).

Laru (2012) examined the phases of mobile learning and used them to distinguish between the eras of mobile, “m-learning” and ubiquitous “u-learning”. His view on mobile and ubiquitous learning is also shared by other researchers proposing alternative definitions, such as personalized learning and handheld learning (Razek & Bardes, 2011). One recent study defines research into mobile learning:

“Research into mobile learning is the study of how the mobility of learners augmented by personal and public technology can contribute to the process of gaining new knowledge, skills and experience” (Sharples et al., 2014, p. 3).

As mentioned in the previous section, over the past decade, there has been an increasing interest among teachers and students in the design and practice of CSCL activities across contexts supported by mobile technologies (Huang & Chiu, 2015). These efforts lead to different deployments emphasizing challenges related to how to design and implement collaborative seamless learning. Chan et al., (2006) addressed aspects related to seamless learning while other researchers followed and further identified and classified them into various dimensions. Specifically, Wong and Looi (2011) addressed challenges related to seamless and mobile learning. They reviewed previous academic papers dealing with topics related to seamless learning and grouped these corresponding aspects under mobile-assisted seamless learning (MSL). Accordingly, they identified ten dimensions that characterize MSL:

(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 type of devices
(MSL-8) Seamless switching between multiple learning tasks
(MSL-9) Knowledge synthesis
(MSL-10) Encompassing multiple pedagogical models

More recent research suggests how novel educational design patterns, mobile technologies and software tools can be used to design future educational activities and technological solutions that could support seamless learning (Milrad et al., 2013). These efforts to design better and more seamless
The matrix illustrated above presents different combinations in which students can practice learning while seamlessly shifting across spaces and between situations. Such seamless activities could be practiced in various types of educational activities including CSL. In such cases, pedagogical designers need to consider and implement means that will offer teachers and students more seamless educational experiences while they shift between activities across locations and situations (Kohen-Vacs et al., 2012a; Chan et al., 2006). In their efforts, they addressed mobile technologies that were gradually discovered and adopted for supporting the implementation of CSL activities. The options can be extended while considering different dimensions related to individual and social learning as well as geo-temporal aspects of the learning situation and the models of interaction (Kearney et al., 2012; Jacob, & Issac, 2014; Muñoz-Cristóbal et al., 2014; Pea et al., 2012).

Practically speaking, seamless learning activities may be conducted along phases in which teachers and students practice educational activities across contexts, as presented in Figure 2.3. The figure above illustrates various aspects and conditions in which I experimented with CSL activities as described in the publications included in this thesis. These aspects aim to specify the different spaces included in the previous matrix. The cases described in this thesis include educational interactions conducted by teachers and students that participated in phases of CSL activities. Some of the phases included planned interactions while in other interactions were emergent. These activities and their goals were implemented...

2.3. Mobile Support for Seamless Educational Activities

Educational activities like those engaged within my exploration efforts consist of learning interactions practiced in different situations across different locations. Similar modes of interactions were also addressed in previous research (Chen et al., 2010; Wong & Looi, 2011; Milrad et al., 2013). Figure 2.2 illustrates a matrix of seamless learning spaces and conditions in which such educational activities can take place.

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Figure 2.2: Matrix of possible learning spaces (adapted from So et al., 2008)
The matrix illustrated above presents different combinations in which students can practice learning while seamlessly shifting across spaces and between situations. Such seamless activities could be practiced in various types of educational activities including CSL. In such cases, pedagogical designers need to consider and implement means that will offer teachers and students more seamless educational experiences while they shift between activities across locations and situations (Kohen-Vacs et al., 2012a; Chan et al., 2006). In their efforts, they addressed mobile technologies that were gradually discovered and adopted for supporting the implementation of CSL activities. The options can be extended while considering different dimensions related to individual and social learning as well as geo-temporal aspects of the learning situation and the models of interaction (physical, virtual and a combination of both). (Kearney et al., 2012; Jacob, & Issac, 2014; Muñoz-Cristóbal et al., 2014; Pea et al., 2012).

Practically speaking, seamless learning activities may be conducted along phases in which teachers and students practice educational activities across contexts, as presented in Figure 2.3.

![Figure 2.3: Aspects to be considered during mobile learning implementations](image)

The figure above illustrates various aspects and conditions in which I experimented with CSL activities as described in the publications included in this thesis. These aspects aim to specify the different spaces included in the previous matrix. The cases described in this thesis include educational interactions conducted by teachers and students that participated in phases of CSL activities. Some of the phases included planned interactions while in other interactions were emergent. These activities and their goals were implemented
and achieved through the realization of various aspects in several settings, practiced by teachers and students organized in various settings. In addition, these interactions were conducted from across locations while being supported by different types of technological devices and tools. The richness of settings attempted to carry out a combination of options as specified in the matrix in Figure 2.2.

The practice of educational activities in such a richness of settings is addressed in previous research efforts. In some of these activities, students were required to interact across different locations (Giemza et al., 2012; Hwang & Wu, 2014; Kohen-Vacs et al., 2012a; Spikol and Milrad, 2008). In such cases, students used technologies aimed to achieve a continuous and seamless learning flow while interacting across a variety of contexts and situations. In some cases, these activities were conducted by students organized in different social settings while shifting between locations or situations (De Jong et al., 2008; Wang, 2005). In addition, teachers and students undertook these activities while relying on devices that are better adapted for ubiquitous usages (Jones & Marsden, 2006; Kukulska-Hulme & Traxler, 2013). These types of CSL activities are described in the publications included in this thesis. Various web and mobile tools, enabling teachers and students to generate content that can later be shared and seamlessly reused across different settings have been used to support these activities.

The activities and the richness of contexts also present various challenges related to the design of such activities. Educational designer and developers should consider the most suitable technological approaches and systems to support teacher-student interactions while designing and participating in collaborative seamless activities. Such infrastructures should aim to enable the planning and exploitation of educational interactions (Wong & Looi, 2011; Milrad et al., 2013).

2.4. Towards the orchestration of seamless learning activities

As implied, web and mobile tools are key aspects that should be addressed while aiming to design and support CSL activities. It is assumed that there is no comprehensive technological support for all possible pedagogical activities practiced across such a multiplicity of contexts. In such activities, different interactions may require support by different tools and technologies. In such cases, an educational process with diverse interactions might be experienced by teachers and students as pedagogically and technologically fragmented. Consequently, the implementation of such activities might require systems’ integration aspects to be considered during the pedagogical design as well as during the technical deployment. Such design and deployment should address
the orchestration of possible educational interactions practiced across contexts (Muñoz-Cristóbal et al., 2015).

The metaphor of orchestration is used to address the design and management of learning interactions conducted along educational activities that are supported by different ICT tools (Dillenbourg & Jermann, 2010). Specifically for CSL activities, orchestration might be required in order to provide teachers with better tools to design educational tasks to be conducted across contexts as well to offer their students more seamless educational experiences (Sharples, 2015). As mentioned, orchestration efforts addressing CSL activities might also require support from several web and mobile tools.

Hoppe (2009, 2015) specifically mentions these interrelated aspects requiring orchestration towards CSL activities. Hoppe (2015) points out challenges associated with social interaction, such as the interaction between individuals or groups. He also points out challenges related to pedagogical strategies, including collaborative learning. He provides possible strategies that can be practiced across locations and situations. Finally, he mentions these challenges in respect of the required technologies to be used for addressing the interrelation of educational interactions practiced across contexts.

From a technological point of view, these challenges related to the orchestration of CSL activities can be met by designing software solutions and tools that aim to enable a more efficient flow of data between environments, systems and tools. Pedagogically, such implementations aim to enable better opportunities for sharing, adopting and reusing educational materials and interactions.

The challenges to the orchestration of pedagogical and technological aspects of CLS were recently revisited by a group of researchers examining different potentials and challenges of CSCL combined with mobile learning. Dillenbourg (2013) addressed orchestration as a term describing how a teacher manages, in real time, multi-layered activities in a multi-constraints context. In addition, he emphasized the need facilitate the flow of information across the mentioned contexts. Tchounikine (2013) considered aspects related to design of such orchestration efforts. Roschelle et al., (2013) summarized different views of orchestration while encouraging further research efforts considering theoretical grounding as well as practical implications. Sharuples (2013) suggested considering such orchestration efforts in light of teachers their students to interact with networked technologies beyond the traditional boundaries of their classrooms.

The different perspectives expressed by various researchers imply that orchestration addresses key aspects closely related to traditional and innovative aspects of learning, which need to be combined, explored and deployed towards a more advanced implementation and exploration of CSL activities. Still, how to address some of the issues related to the design of tools and systems to support and orchestrate collaborative seamless learning remains a challenging task.
3. Research Approach

In this chapter, I discuss the methodological aspects related to my research. I start by discussing the research needs, followed by an introduction of my main research aims and questions. I give a brief description of the research settings in which my efforts took place. Thereafter, I present the methodological considerations that guided my efforts and served to explore the research questions. Next, I describe the research activities and end with a summary addressing my research by introducing the different scientific publications I have produced.

3.1. Research Need

The research described in this thesis relates to the design, development, deployment and evaluation of different software solutions that integrate web and mobile tools to support CSL activities. The crucial role of ICT for supporting such activities has been identified and explored by the community of researchers (Hoppe et al., 2007; Lipponen et al., 2004; Pea et al., 2012; Sharples et al., 2014; Zurita & Nussbaum, 2007). In this sense, my research aims to further contribute to these efforts by exploring ways to best design systems and tools to support teachers and students during CSL activities.

During my research, I faced various challenges dealing with the discovery and analysis of the requirements for the expected functionalities of those solutions. One important challenge relates to the transformation and implementation of these requirements into software tools to be deployed and used in authentic educational settings. The development and deployment of these ICT solutions address the following aspects:

- Design of software components and tools used to support educational interactions conducted along the different phases of CSL activities;
- Deployment of integrated web and mobile tools enabling flow of educational content that can later be shared and reused by teachers and students;
- Exploitation of the mentioned tools for evaluating teachers and students’ experiences acquired during the different CSL activities.

In the next section, I present my research aim and questions addressing these challenges.

2.5. Summary of ideas described in this chapter

In this chapter, I discussed aspects related to the evolution of CSCL supported by mobile technologies. In addition, I presented various examples of CSCL activities that could be deployed and practiced across contexts, followed by a description of the specifications used to support them. I then presented the evolution in mobile technologies and their affordances to support CSL activities practiced across contexts. I concluded by presenting different affordances and challenges related to the orchestration of this kind of activities supported by different technological solutions, which in many cases is fragmented and does not take into consideration interoperability and integrative aspects. The series of topics presented in this chapter illustrate the wide scope of topics explored by the TEL community (Bordiés et al., 2012; Demetriadis and Karakostas, 2008; Hernández-Leo, 2007; Hoppe, 2009). In what follows I will present aspects related to my research that address the deployment of CSL activities supported by web and mobile technologies in order to cope with the mentioned technological fragmentation problem. The research, including design, deployment and exploration efforts, is an attempt to find innovative ways to provide teachers and students with better educational activities that will be experienced more seamlessly. The deployment and methodological approaches selected to implement these efforts are described in the next chapter.
3. Research Approach

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3.1. Research Need

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- Exploitation of the mentioned tools for evaluating teachers and students’ experiences acquired during the different CSL activities.

In the next section, I present my research aim and questions addressing these challenges.
3.2. Research Questions and Research Goals

Since my research deals with challenges related to the design, development, deployment and evaluation of web and mobile solutions used to support CSL activities, the main challenge pursued in my research aims to answer the following question:

*How to best design systems and tools to support students during the enactment of collaborative seamless learning activities and to provide teachers with artifacts to design and assess those?*

In order to further elaborate on this challenge, the following research questions (RQ) have been formulated and enumerated as following:

- **RQ1-** How to transform learning requirements into guidance addressing technological deployments aimed to support CSL activities?
- **RQ2-** How to design and deploy web and mobile tools that enhance flow, share and reuse of learner generated content along the different phases of CSL activities?
- **RQ3-** Which methods should be used in order to assess CSL activities and the tools deployed and exploited for supporting them?

In the following subsections, I discuss different methodologies and approaches used to explore these research questions. The last section in this chapter presents my research activities as described in my publications that address the mentioned RQs.

3.3. Research Settings

In this subsection, I briefly present the research settings used for 3 different activities later described in the papers included at the core of this thesis.

The first activity (referred as case #1 in chapter 4) was carried out with 1st year bachelor students that attended a course on Interface Design. In this activity, 37 students interacted along 5 phases practiced during several days. During these activities, students used web and mobile tools in order to interact both from indoors and outdoors.

The next activity (referred as case #2 in chapter 4) was presented to 25 bachelor and master students that attended a course on negotiation and conflict management. This activity included 5 phases conducted along several days.
During these phases, students were required to interact using different web and mobile tools from their classrooms as well as from their homes.

The last activity (referred as case #3 in chapter 4) was carried out with 75 students attending courses at the bachelor level at two different academic institutions in two countries. These students attended three different courses dealing with topics in Computer Science. They participated in an activity that included 3 phases conducted along several days. In this activity, students used a variety of ICT tools to interact from their classrooms, workplaces and homes.

3.4. Methodological Considerations

During the development and research efforts carried out along the last five years, I used various methodologies in order to address various aspects of the research. First, the elicitation of requirements was discovered while practicing a well-known approach consisting of inquiry, documentation and validation addressing TEL requirements (Alexander & Dukic, 2009; Hay, 2003; Heron, 1996). Specifically, during this process I aimed to identify stakeholders, their goals and use cases in which they could be involved. The outcomes of these efforts were later utilized to address web and mobile tools to be used during the different CSL activities.

In the next stage, I aimed at transforming the mentioned requirements into a set of functionalities needed during the enactment of the CSL activities. These functionalities were achieved through the design and development of different and integrated tools were used to support various types of CSL activities. These activities were examined and refined while using an approach referred to as Design-Based Research (DBR) (Brown, 1992; Collins, 1992; Collings et al., 2004; Hoadley 2002). DBR is normally practiced in processes in which researchers intervene, consider and implement their concepts in natural settings. Later research mentions the importance of DBR for the field of TEL. Specifically, Ravenscroft et al., (2012) claim that future TEL designs will tend to be iteratively performed and co-evolve with learning practices. The efforts carried out in this research are much in line with these ideas. Accordingly, the CSL activities presented here were iteratively conducted, examined and refined. In this iterative process, I examined interrelated pedagogical and technological aspects emerging from practiced and explored activities. Such an iterative process adheres to the principles proposed by Ravenscroft et al., (2012) in their overview of the MATURE Design Process.
3.5. Deployment and Research Approaches
I begin by describing my efforts to elicit a set of TEL requirements for developing and deploying different software solutions to support CSL activities. I then use the elicited requirements for identifying functionalities needed in the CSL activities. These functionalities were designed and implemented and later refined and assessed relying on DBR. Figure 3.2 describes the sequence of efforts and methods that guided my efforts.

The sequence begins with an iterative process of discovery and elicitation of requirements aiming at the functionalities that need to be designed. In the next step, these functionalities are developed and then deployed. These efforts deal with the development of web and mobile tools aimed for use during the CSL activities. The actual use also is iteratively assessed and refined while using different evaluation methods that may result in refinements in terms of design or in terms of modes of use (deployment).

In the following subsections, I elaborate on TEL requirements later used to guide the design process. Next, I present an approach used for design CSL activities. I conclude these subsections while presenting an approach to assess technological acceptance practiced for one the activities described in this thesis.

3.5.1. Discovery of TEL Requirements for CSL
In this subsection, I describe my approach to the discovery, analysis and eliciting of TEL requirements used to design and deploy different solutions to support CSL activities.

Figure 3.1 below illustrates Ravenscroft’s et al., (2012) model including aspects and principles utilized also for the cases discussed in this thesis.

This figure illustrates the cyclic process starting with prioritization that results in the interpretation of a problem or reflection gained in a previous cycle. This is later transformed into objectives of what needs to be designed and later evaluated. The outcomes of the steps in this cycle interact with a conceptual model that could be later shared. As mentioned, these different cycles including prioritization, concretization of the learned aspects, design and evaluation – were also used for the design process exercised prior to the actual development of the tools later used to support the cases presented in this thesis. It should be mentioned that in the evaluation process blended methods consisting of quantitative and qualitative approaches (Papamichael, 2007; Sherman & Webb, 2004) have been used.

In the next section, I present and discuss how these methodological approaches have been applied during my development and research efforts.
3.5. Deployment and Research Approaches

I begin by describing my efforts to elicit a set of TEL requirements for developing and deploying different software solutions to support CSL activities. I then use the elicited requirements for identifying functionalities needed in the CSL activities. These functionalities were designed and implemented and later refined and assessed relying on DBR. Figure 3.2 describes the sequence of efforts and methods that guided my efforts.

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3.5.1. Discovery of TEL Requirements for CSL

In this subsection, I describe my approach to the discovery, analysis and eliciting of TEL requirements used to design and deploy different solutions to support CSL activities.
In the discovery process, I addressed several and interrelated aspects including:

- Identification of the stakeholders related to my deployment efforts (teachers, students and developers);
- Discovery of educational and technological goals as reflected from the stakeholders;
- Identification of educational scenarios for CSL activities that address the discovered goals;
- Identification of technological means to support the enactment of CSL activities.

Each of the mentioned aspects shares the same process, including discovery, documentation and validation, as described in Figure 3.3.

![Figure 3.3: Steps in an iterative discovery process of TEL requirements](Image)

The identification of stakeholders represents a crucial aspect of defining system requirements. This aspect addresses the identification of individuals or groups that are likely to affect or be affected by a proposed project (Angelov & Hilliard, 2014; Fletcher et al., 2003; Jepsen & Eskerod, 2013; Reed et al., 2009). Accordingly, the identification of stakeholders was also practiced for the CSL cases presented in this thesis. Specifically, my inquiry process aimed to target teachers interested to offer their students (also considered as stakeholders) to practice CSL activities. Identified stakeholders were constantly tracked with proper documentation stating their identities and roles in terms of their tasks along the technological deployment, as well as their tasks during actual enactment of the CSL activity. This documentation; addressing stakeholders was validated while constantly checking and updating the mentioned aspects.

The identification of stakeholders was followed by another process, aimed to discover their goals. Goals should reflect stakeholders’ intentions in terms of what they want to achieve within the scope of a project (Alexander & Beus-Dukic, 2009). Accordingly I dealt with discovering and documenting high-level goals as well as practical goals related to the design and deployment of various
CSL activities. Stakeholders were asked to state their positions vis-à-vis the pedagogical activity and the technological tools required for supporting it. One of the main tasks related to the discovery of goals consists of their consolidation into a document that specifies in the context of their overall mission. Finally, this statement of goals was validated in terms of its ability to comply with conditions set by the stakeholders (Pohl, 2010).

In the next step, the goals were converted into actual scenarios addressing CSL activities supported by the deployed tools. One of the main concerns was to design scenarios that reflect structured stories as conceptualized both by teachers, students and developers (Papavasiliou et al., 2011). The term “Pedagogical Scenario” is commonly used to describe the learning process (Dillenbourg, 1999). For the described cases, scenarios were discovered by interviewing teachers, students and developers (Sutcliffe, 2012; Van Lamsweerde, 2009). The discovery of a scenario takes into account the nature and settings for practicing interactions along it. These aspects were documented, described in diagrams and texts and were later validated. The validation focused on finding missing phases, or representation of phases in the wrong order. In addition the documentation was examined in order to reveal a lack of actions that should have been conducted along the phases of the scenarios.

TEL requirements should also address to the technological means to support the enactment of CSL activities. During these activities, teachers and students were supported by web and mobile tools used for various purposes. The various aspects of these interactions are reflected in a series of MSLs as identified by Wong and Looi (2011). These interactions dealt with the generation of content, sharing it and reusing it along various phases of the CSL activities. The implementation of the CSL scenarios presented in this thesis illustrates the generation, sharing and reuse of content performed by the students using the different tools that were developed. In practice, the generation of content was supported by the tools' interfaces, enabling teachers and students to interact. Sharing and reusing of content was enabled by tools inter-operating through dedicated middlewares and services (Alexander and Beus-Dukic, 2009).

In this subsection, I presented aspects to be included in the elicitation of TEL requirements. As mentioned, the initial deployment supported by TEL requirements served as a starting point from which additional exploration and refinement efforts are conducted.

The mentioned process addressing elicitation of TEL requirements is central for the development and deployment of technologies that aim to support CSL activities. Specifically, the activities described in this thesis were supported by integrated environments and systems enabling teachers’ and students’ interactions while using various web and mobile tools. The development of these tools relies on various web and mobile technologies described in the following chapter.

I describe next how DBR has been used to further refine the scenarios and tools of the deployed CSL activities.
3.5.2. Design Based Research

DBR emerged following an urgent need for an improved approach towards educational technology research (Hoadley, 2002). During my research I considered five characteristics associated with DBR and suggested by the Research Collective (2003):

- Design of learning environments and developing theories of learning as intertwined topics;
- Practice of iterations during development and research;
- Dissemination of theories aimed to share insights with other practitioners (Barab and Squire, 2004; Easterday et al., 2014);
- Exploration of design in authentic settings;
- Documentation that reflects processes related to enactment and corresponding outcomes.

Figure 3.4 describes the iterative efforts performed across my research efforts according to DBR.

The figure above details and emphasizes specific steps prior and after transformation of functionalities to design. Specifically, it details how discovered requirements are eventually refined and transformed to functionalities to be designed, developed and tested in later steps of the process. This illustration aims to emphasize on specific steps also reflected from Figure 3.2 and Figure 3.3.

Figure 3.4: Illustration of the DBR process applied to my research.
3.5.3. Evaluation Approach

In section 3.4 of this chapter I presented the Mature Design process as adapted from Ravenscroft et al., (2012). This process, as illustrated in Figure 3.1 points out on how requirements are prioritized, learned and considered for designs. In addition, I also mentioned that these design are evaluated with target users providing insights considered for additional iterations of refinement. This process is considered for evaluation of CSL activities while aiming to eventually convert them in more mature concepts.

Accordingly, the enactments of the CSL activities in this thesis were iteratively tested and refined while relying on quantitative and qualitative blended methods (Thomas, 2003). Quantitative methods included analysis of outcomes from tasks presented to students across various CSL activities. These tasks consisted the use of Likert scales to vote and assess for artifacts contributed by students along the phases of the activities (Papamichael, 2007; Sherman & Webb, 2004). In addition, questionnaires were presented while aiming to focus on how various aspects of the educational experiences was perceived by the students.

The contributed content were statistically analyzed while seeking and examining these content in terms educational designs as well as in terms of technologies used to support them. Specifically, these analysis were based on students’ interactions dealing with rating and assessing artifacts generated by their peers.

The evaluation of the different CSL activities also relied on qualitative methods. The activities were followed by semi-structured interviews with teachers and students. These interviews addressed the acceptance and perceived usefulness of environments, systems and tools used to support the activities. In the last case, I used another method aimed to assist with the evaluation of the degree of acceptance of the technology.

Data collected from interviews also served to validate information collected quantitatively. The outcomes of these data collections was used to assess the perceived insights as expressed by teachers and students participating in CSL activities. These outcomes were then used to introduce refinements that addressed both the technological aspects and the pedagogical design. These refinements were later re-tested in further iterations (Wang and Hannafin, 2005).
Finally, for case number 3 presented in this thesis, I conducted an evaluation using the Technology Acceptance Model (TAM) approach (Davis, 1989) as illustrated in Figure 3.5.

![Figure 3.5: Interdependent aspects in TAM](image)

This approach was practiced for assessing students' views of the usefulness and ease of use of the tools implemented for the CSL activities. TAM assessment was supported by a questionnaire introduced to the students following their participation in the CSL activities. This questionnaire included a series of statements for each student, which were requested to express their level of agreement (Likert, 1952).

### 3.6. Mapping the different research efforts to the research questions

In the year 2010, we concluded an initial step dealing with development and research on how to support the orchestration of CSCL relying on the CeLS environment (Ronen & Kohen-Vacs, 2010). We published the outcomes of this research that spanned over four years in a book chapter that presented different techniques for fostering collaboration in online learning communities. The book chapter presented the CeLS environment that provides teachers of all subjects and levels with a flexible tool for creating, enacting, and sharing CSL activities. CeLS’s special feature is the controllable data flow: the ability to selectively reuse learner artifacts from previous stages according to various social settings in order to support design and enactment of rich multi-stage...
scripts. In the following years, we noted an increasing interest among teachers and students to design and practice these kind of activities beyond the traditional boundaries of their classrooms. Accordingly, I commenced a new phase in my research addressing these developments. These efforts evolved and developed and were later published in an article conceptualizing the design and deployment of CSL activities (Milrad et al., 2011). In further steps, these concepts were tested with different CSL activities supported by web and mobile tools integrated with CeLS. Subsection 3.3 provided an initial description of the different settings for these tests activities. Since then, I have conducted several experiments to explore different aspects of my research aim and questions. These efforts have resulted in several scientific publications that have been published during the last 5 years. They are described in the following list of publications:

**Paper #1:**

**Paper #2:**

**Paper #3:**

**Paper #4:**
Below I present a classification of the different papers according to different topics associated to the research questions:

- Previous efforts: Orchestration and enactment of CSCL activities (RQ-1, 2): paper #1
- Conceptualization of CSL activities (RQ-1, 2): paper #2
- Elicitation of requirements for guiding design and development of technologies used for supporting CSL activities (RQ-1): papers #4 and 9
- Developing, deployment and evaluation of three CSL cases conducted in real settings across domains and levels (RQ-1, 2, 3): papers #3, 5, 6, 7 and 8
- Evaluation of CSL cases conducted in real settings across domains and levels (RQ-3): papers #8 and 9

The next chapter presents a more detailed description of each one of these publications including the aims, activities and outcomes in relation to sub-questions RQ [1-3] and the main RQ.

**Paper #5:**

**Paper #6:**

**Paper #7:**

**Paper #8:**

**Paper #9:**

In these different papers, I address various aspects of CSL activities and technologies, including the conceptualization, development orchestration and enactment of those. In addition, I address the deployment and evaluation of these activities.
Below I present a classification of the different papers according to different topics associated to the research questions:

- Previous efforts: Orchestration and enactment of CSCL activities (RQ-1, 2): paper #1
- Conceptualization of CSL activities (RQ-1, 2): paper #2
- Elicitation of requirements for guiding design and development of technologies used for supporting CSL activities (RQ-1): papers #4 and 9
- Developing, deployment and evaluation of three CSL cases conducted in real settings across domains and levels (RQ-1, 2, 3): papers #3, 5, 6, 7 and 8
- Evaluation of CSL cases conducted in real settings across domains and levels (RQ-3): papers # 8 and 9

The next chapter presents a more detailed description of each one of these publications including the aims, activities and outcomes in relation to sub-questions RQ [1-3] and the main RQ.
4. **Overview of Studies**

In the previous chapters, I presented past and ongoing research efforts discussing different aspects of mobile learning. I specifically referred to the advances in the field while addressing the combination of CSCL strategies and mobile learning (Kobbe et al., 2007; Kollar et al., 2006; Zurita & Nussbaum, 2007). I further addressed challenges in mobile learning as expressed by Chan et al., (2006) and later elaborated by Wong and Looi (2011). More recent research and implementation efforts were addressed in various recent publications (Milrad et al., 2013; Muñoz-Cristóbal et al., 2015; Sharples, 2015). In this chapter I present my particular research efforts addressing different aspects of CSL activities (Wong, 2012). I begin with an overview of all the publications included at the core of this thesis that illustrate theoretical and technological aspects; as well as three cases for which I conducted empirical activities in real educational settings. For each one of the publications, I provide an executive summary and the results and outcomes. I then describe the software components that have been developed to support each one of the activities. The chapter concludes with a summary discussing all these efforts.
4.1. Overview of Publications

As already described in section 3.6 of the previous chapter, nine scientific papers have been published during the last 5 years. Table 4.1 provides an overview of those publications, the RQs they are addressing and the main aim of those. Thereafter, each one of the papers is described in more details.

<table>
<thead>
<tr>
<th>Paper number</th>
<th>Addressed RQ</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper #1</td>
<td>RQ-1, 2</td>
<td>To present the potentials and challenges of CeLS to foster and support the use of collaborative techniques in actual educational settings.</td>
</tr>
<tr>
<td>Paper #2</td>
<td>RQ-1, 2</td>
<td>To describe various efforts that combine the potentials and affordances of two approaches and systems aiming to provide teachers and researchers with the ability to design and enact CSL scenarios.</td>
</tr>
<tr>
<td>Paper #3</td>
<td>RQ-1, 2, 3</td>
<td>To describe a practice approach that combines the potentials and affordances of two approaches and systems used by teachers and students during CSL activities conducted at indoors and outdoors.</td>
</tr>
<tr>
<td>Paper #4</td>
<td>RQ-1</td>
<td>To explore and describe potential and challenges of integrating collaborative and mobile technologies in order to support a wide variety of CSL activities practiced across contexts.</td>
</tr>
<tr>
<td>Paper #5, 6</td>
<td>RQ-1, 2, 3</td>
<td>To explore and discuss efforts focused on introduction of new mode of interactions supported by Personal Response Systems (PRS) into CSL activities.</td>
</tr>
<tr>
<td>Paper #7, 8</td>
<td>RQ-1, 2, 3</td>
<td>To explore and evaluate the design and implementation of an interactive environment that relies on web and mobile solutions offered to teachers and students for authoring and incorporating educational interactions at specific moments along the time line of occasional YouTube video-clips.</td>
</tr>
<tr>
<td>Paper #9</td>
<td>RQ-1, 2, 3</td>
<td>To further elaborate on challenges related to our ongoing efforts to integrating various TEL environments in order to support the design and implementation of CSL activities practiced.</td>
</tr>
</tbody>
</table>
4.1.1. Paper #1

**Title:** Modeling, Enacting, Sharing and Reusing Online Collaborative Pedagogy with CeLS

**Executive summary:** This chapter presents the potential and challenges of a new approach for the design of a platform aimed to foster and support the use of collaborative techniques in actual educational settings. CeLS is a web-based environment aimed to provide teachers of all subject domains and levels with a flexible tool for creating, enacting and sharing CSCL activities. CeLS’s special feature is the controllable data flow: the ability to selectively reuse learners’ artifacts from previous stages according to various Social Settings in order to support design and enactment of rich multi-stage scripts. CeLS offers content-free templates and a searchable repository of sample activities previously implemented with students. Teachers can explore these resources and adapt them to suit their needs, or create new scripts from basic building blocks. During the last four years the system was piloted by teachers from 13 colleges and universities and by school teachers. The chapter presents the CeLS approach focusing on its unique features, examples of activities implemented with students and some insights on teachers as developers of online collaborative activities and as active contributors to the development of the environment.

**Outcomes:** The results described in this publication offer a web approach for design and enactment of CSCL scenarios. These practical affordances are offered while elaborating on various TEL requirements that need to be addressed for such implementations (RQ-1, 2). This paper presents the implementation of the CeLS web environment that enable to orchestrate, enact, share and reuse multiphase CSCL scenarios. The functionalities provided by this environment are later exploited for the cases described in the papers presented below. Specifically, the outcomes of these efforts are used to support the orchestration of the scenarios practiced along the different CSL activities extensively described in papers #3, 5, 6, 7, 8.

4.1.2. Paper #2

**Title:** An Integrated Approach for the Enactment of Collaborative Pedagogical Scripts Using Mobile Technologies

**Executive summary:** This paper describes our current efforts to combine the potential and affordances of two approaches and systems aiming to provide educators and researchers with the ability to design and enact pedagogical
scripts to support collaborative learning activities in classroom and outdoors settings.

**Outcomes**: In this paper, we explain how the different technical features of our systems have been integrated combining web-based solutions and mobile applications. One illustrative scenario is described and discussed in order to provide a better understanding of the different aspects and outcomes resulting from the integration of our approaches. Our initial results indicate the potential benefits of our approach in order to support and orchestrate collaborative learning trajectories across different contexts. The outcomes of this publication were used to assist with designing, developing and deploying the CSL activities practiced and described in papers #3, 5, 6, 7 and 8.

### 4.1.3. Paper #3

**Title**: Incorporating Mobile Elements in Collaborative Pedagogical Scripts

**Case 1**: Orchestration of CSL activity practiced indoors and outdoors

**Executive summary**: This paper describes our on-going efforts in combining the potential and affordances of two approaches and systems that can be used to provide teachers with the ability to design and enact online learning scenarios that include activities performed in outdoor settings. We describe how different technical features of our systems have been integrated combining web-based solutions and mobile applications. We present a detailed example of a learning scenario that was implemented with undergraduate students and included outdoor activities performed via mobile phones, as well as other learning tasks using the web and computers in the classroom and at home. Our results imply of ways teachers and students may use technology in order to support collaborative learning trajectories across different contexts, as well as insights pointing to the pedagogical and design challenges involved in combining a variety of technologies to support outdoors and indoors learning activities.

**Outcomes**: In this paper, I deal with how to orchestrate an activity practiced in various classroom settings and conducted across locations. Here, I illustrate how the combination of mobile and stationary technologies can support different phases of the learning experience that cross spatial, temporal and conceptual boundaries, and interweave with the learner’s everyday life and into her web of personal knowledge, interests and learning needs. Furthermore, we elaborate on location and time settings to be specify in the learning scenario for the design and deployment of CSL activities.
4.1.4. Paper #4

Title: Systems Integration Challenges for Supporting Cross-Context Collaborative Pedagogical Scenarios

Executive summary: This paper discusses the potential and challenges of integrating collaborative and mobile technologies in order to support a wide variety of learning activities across contexts. We present and illustrate two examples of such integrations aiming to expand the functionalities of an existing CSCL environment by introducing mobile technologies. Our goal is to enable the design and enactment of pedagogical scenarios that include asynchronous learning, outdoor collaborative activities and tasks performed in class using personal response systems. These examples are used to identify and analyze different challenges related to software systems integration issues. The outcome of these efforts is a proposed cross-context systems integration model that can serve as the basis for future work that leads towards the integration of additional mobile applications designed and implemented to support novel collaborative learning scenarios.

Outcomes: In this paper, I examine the potential and challenges related to systems’ integration for supporting CSL activities. This examination includes an analysis focusing on three different challenges related to such activities including conceptual, architectural and engineering (RQ-1). The outcomes of this publication summarize my early research and development efforts. I also present a preliminary architecture for such systems’ integration and illustrate key aspects that need to be considered for its implementation.

4.1.5. Paper #5

Title: Integrating SMS Components into CSCL Scripts

Case 2: Orchestration of CSL activity enabling students to interact in various modes along its phases (applies to 5 and 6)

Executive summary: This paper presents an effort to enrich and expand the potential of CSCL scripts by combining different technologies. We introduce and describe a dedicated SMS personal response system designed to support class activities and its integration with CeLS, an environment used to design and enact online collaboration scripts.
4.1.6. Paper #6

Title: Integrating Collaborative and Mobile Technologies for Fostering Learning about Negotiation Styles

Executive summary: This paper presents and discusses our efforts aiming to expand the potential of an existing CSCL environment through integration with additional software applications in order to support a cross-context learning activity. We used a CSCL environment for supporting asynchronous types of interactions, mobile devices for face-to-face interaction and a dedicated web application for self-assessment. We present the design and implementation of a scripted learning activity that deals with negotiation styles and describe the integration of different software applications that supported the students’ interactions along the various activity phases. The results indicate the potential and benefits of the integrative approach using collaborative and mobile technologies in order to support and enhance a wide range of pedagogical activities.

Outcomes (for both publications of case 2): In this activity, I put a special emphasis on requirements for designing tools enabling students to better construct knowledge by engaging and inspiring them to learn (RQ-1). Another outcome concerns the development and deployment of tools enabling students to seamlessly shift between different educational activities. In addition, these tools also enabled students to shift between personal and social learning. Another technological aspect concerns the integration of these technologies for enabling data flow and reuse of content generated in various tools and used along different phases of the activity (RQ-2). Finally, these generated content was presented to students in the final debriefing session. In addition, these content was also used for evaluation purposes (RQ-3).

4.1.7. Paper #7

Title: Integrating Interactive Videos in Mobile Learning Scenarios

Case 3: Orchestration of CSL activity enabling students to author and interact with interactive videos (applies to 7 and 8)
Executive summary: Nowadays, there is a growing variety of mobile devices and online video content that could be used to support a variety of pedagogical strategies used for different cross-context learning scenarios. In order to take advantage of these developments, this paper presents an approach that allows integrating learning material represented as videos in mobile learning scenarios, mainly by the implementation of a mobile client that presents learning material as small chunks of video content. The application of these ideas can potentially provide new educational opportunities to support learning across different contexts. Additionally, the videos consumed by the mobile client allow the integration of interactive elements like questions that could be answered by the learner while viewing the video or additional comments that could be provided to assist the learner. The rationale for the integration of the interactive parts in the video is to increase learners’ engagement and therefore also to increase their involvement and participation in order to generate an active learning experience.

4.1.8. Paper #8

Title: Evaluation of Enhanced Educational Experiences Using Interactive Videos and Web Technologies: Pedagogical and Architectural Considerations

Executive summary: In this paper I describe the design and deployment of a CSL activity dealing with authoring, using, sharing and assessing interactive videos. I elaborate on how my technological deployment was used by teachers and students to better access to educational and rich media resources, wherever and whenever necessary. In this sense, I present EDU.Tube: an interactive environment that relies on web and mobile solutions offered to teachers and students for authoring and incorporating educational interactions at specific moments along the timeline of occasional YouTube video-clips. The teachers and students could later experience and address these authored artefacts while interacting from their stationary or mobile devices along the phases of the CSL activities.

Outcomes (for both publications of case 3): The outcomes of this activity impact both technological and pedagogical aspects. The first outcome concerns the orchestration of an activity used for supporting educational, interactive video-clips authored and experienced across locations (RQ1). In addition, the architecture deployed for this activity enabled generation, share and reuse of interactive videos among teachers and students (RQ-2). The technologies deployed in this activity enabled to experienced video-clips both on regular computers and also on mobile devices. Accordingly, one of the outcomes concerns the adaptation of rich and interactive media to mobile devices. Other
outcome concerned the authoring of educational content. In this respect, another outcome addresses the creation of new and interactive educational video-clips shared and reused by peers in present or in future courses (RQ-2). Finally, I also present a way to assess such activity while employing blended methods (RQ-3).

4.1.9. Paper #9

**Title:** Fragmented yet Seamless: System Integration for Supporting Cross Context CSCL Scripts

**Executive summary:** Complex multi-stage pedagogical activities may address different planes (temporal, social, physical) by different pedagogical strategies. Since there is no comprehensive technological support for all possible pedagogical practices, activity phases may be supported by different technologies, adapted to the specific needs of the particular stage. As a result, the implementation of such activities could feel technologically “fragmented”, since data collected with one system will not be available for immediate use in another environment. This technological fragmentation may not only obstruct the enactment of such activities, but even discourage teachers and prevent them from designing rich pedagogical experiences supported by different technologies. Therefore, in order to provide a seamless learning experience, there is a need to ensure continuous data flow between the activity phases enacted with different technologies. This research presents our ongoing efforts to cope with the challenge of integrating various TEL environments in order to support the design and implementation of cross context, multi-stage collaborative activities.

**Outcomes:** in this publication, I offer a later elaboration of my research efforts dealing with CSL activities. Here, I elaborate on requirements for orchestration of activities that include flow, share and reuse of content along phases of CSL activities. In addition, I provide an overview of scenarios and web and mobile technologies used to support them. Finally, I address an evaluation of activities that where designed while using educational, organizational and technological requirements (RQ-3)
4.2. Description of the different software components

In this sub-section I provide a brief description of the different software components that have been developed to support the various activities described in the papers. They all represent a set of tools and systems that can be combined and used in interactive learning environments to support collaborative seamless learning.

CeLS (discussed in paper #1) stands for Collaborative e-Learning Structures. The CeLS environment aims to enable teachers and students to design, enact, share and reused pedagogical strategies (Ronen & Kohen-Vacs, 2010). This environment also aims to enable orchestration of educational interactions practiced along phases of CSCL activities. It provides teachers with visual interfaces enabling them to author and enact learning scenarios. CeLS authoring functionalities rely on several types of building blocks enabling teachers to plan educational interactions to be practiced along phases of CSCL activities. The building blocks are assigned to several families, including:

- **Presentation** blocks used for enabling passive display of information in various formats like text, links, sound and video clips.
- **Input** blocks used for authoring interactions that require input in various forms, including simple text and rich media, single selection, multiple selection, sorting and categorizing.
- **Interaction** blocks used while planning educational tasks that rely on data that was contributed in previous phases of CSCL activities. This family of building blocks enables authoring of educational interactions for supporting peer assessment type of educational strategies. The interdependent nature of this family emphasizes the challenges related to modifications that may occasionally be required in real time during the enactment of such activities. These challenges were addressed in in our previous publication (Ronen & Kohen-Vacs, 2009).
- **Communicational** building blocks used to establish communication sessions between students participating in an activity.
- **Operational** blocks do not affect the student’s interface. They provide authors with the ability to assign participants into groups according to different criteria based on their inputs and actions.

The mentioned building blocks are implemented using .NET web technologies enabling to author and design of CSL activities while using the various and mentioned types of components. In addition, I used XML based format to annotate their orchestration as well as SQL server to store such...
The actual design consists of authoring sequences of building blocks included in any phase of a CeLS activity. The organization of these building blocks is crucial for enabling the orchestration of CSL activities in different ways as addressed in the research questions.

**MoCoLeS** (discussed in paper #2 and 3) stands for Mobile Collaborative Learning System and represents an early developmental effort deployed and interoperated with CeLS (Kohen-Vacs et al., 2011). This system enables conducting indoor and outdoor interactions supported by mobile devices. MoCoLeS relies on various cloud technologies including XForms and cloud storage. MoCoLeS was introduced to teachers and students to interact from outdoors with their own mobile devices. These interactions were shared and reused along phases of the educational activity.

**SMS-HIT** (discussed in papers # 5 and 6) is a Personal Response System (PRS) offering teachers and students support for their educational interactions through various devices in real time in classroom lessons practiced in traditional modes (i.e. face to face lessons). Interactions supported by SMS-HIT can use various types of devices including mobile phones. SMS-HIT was developed while relying on .NET and MVC 4 projects integrated to SQL server. The client side of this system relies on various technologies including HTML5, CSS, JavaScript, JQuery and Ajax. The last mentioned technologies aimed to enable rich interaction combined with efficient User Experiences (UX).

Interactions in this system could be conducted through SMS messaging or web environments (Kohen-Vacs et al., 2012c; Kohen-Vacs et al., 2012d). In this thesis, I include two publications demonstrating how teachers and students interact in traditional lessons while being supported by SMS-HIT.

**NeSI** (discussed in paper #6) is a system aiming to offer diagnosis for one’s natural negotiation. This system is supported by an algorithm based on Rahim’s (1983) questionnaire for measuring negotiation styles during interpersonal conflicts. The development of this algorithm was based on C# .NET technologies enabling to use it on a web interface as well as to share and reuse its content with other environments (Kohen-Vacs et al., 2012).

**EDU.Tube** (discussed in papers #7 and 8) represents the latest development and deployment effort aimed to enable teachers and students to transform occasional video clips found in YouTube into rich and interactive educational experiences (Kohen-Vacs et al., 2014; Kohen-Vacs et al., 2013). The EDU.Tube authoring environment enables teachers and students to author educational interactions and to incorporate them into moments along the timeline of the YouTube video. Later, teachers and students can experience these educational and interactive opportunities from various technologies including mobile devices. EDU.Tube is also integrated into CeLS in order to experience
interactive videos along phases of CSL activities. EDU.Tube authoring system relies on .NET technologies integrated with the SQL server. In addition it is also supported by HTML5 and JS libraries. The mobile instance of EDU.Tube is supported by HTML5, CSS3 and JavaScript libraries integrated, compiled and later shared as web environments adapted to various type of devices having different operating systems.

4.3. Summary

In this chapter I described in detail each one of the scientific publications that are at the core of this thesis. I presented my research efforts aligned to the challenges previously addressed when it comes CSL activities. As already stated, one of the main topics of in my research are related to design, development and deployment of environments, systems and tools aiming to enable better orchestration of CSL activities. My efforts are related to previous research of seamless and mobile learning (Chan et al., 2006; Kukulska-Hulme et al., 2009; Sharples, 2015; Wong & Looi, 2011). Figure 4.1 illustrates the sequence of the different publications and their contribution to my efforts.

Figure 4.1: Sequence of research efforts
As illustrated, the first effort addressed the initial exploration of CSCL activities supported by the CeLS environment. In that phase, I examine the deployment, orchestration and assessment of CSCL activities. During the next phase, I started to conceptualize different CSL activities supported by various tools that were catalyzed by CeLS. Next, we practiced several interventions as reflected in cases 1-3. In these interventions, I addressed the research questions by introducing new tools for better support, sharing and reuse of content contributed by teachers and students in the context of CSL activities. These cases were assessed in terms of both, technological and pedagogical affordances to enable better support for complex educational process practiced along phases of CSL activities. These technologies enable teachers and students to exploit educational opportunities found in real settings while being supported by various and integrated solutions. The research carried out in this process included several cases that were refined through process aiming to refine and enable the deployment of matured designs for CSL activities (Ravenscroft et al., 2012). These refinements impacted design, development and deployment of the cases practiced and assessed throughout this thesis. Specifically, in this process, I addressed various aspects including educational, organizational and technological aspects of the activity. These aspects have influence both on the educational strategies as well as on the technologies used to support them.

In the following chapter I will discuss and analyse the findings emerging from the results and outcomes discussed in this chapter.
5. Analysis and Discussion of Results

In the previous chapter, I discussed the different activities including their aims and outcomes as presented in the papers included at the core of this thesis. In this chapter, I analyse and discuss the outcomes of these research efforts. The analysis of these results is guided by the theoretical ideas discussed in chapter 2. I commence this chapter by providing a detailed elaboration of the results for each of the practiced CSL activities. In the next subsection, I begin with a presentation dealing with the units of analysis used for different activities. In addition, I present the role of the MSL dimensions for each of these units. Next, I elaborate on various considerations for each of the practiced activities in the light of the discussed MSLs. In the following subsection, I present the dimensions used to address the requirements considered in the design process. I continue with a discussion addressing design towards the deployment of concepts for CSL activities. I then conclude this chapter while presenting my contributions to the research aim and questions.
5.1. **Units of Analysis**

In this subsection, I elaborate on various aspects related to the design and deployment of CSL activities. Figure 5.1 describes the different units of analysis that have been used to guide and inform the different activities.

![Figure 5.1: Overview of sequenced design and deployment](image)

In the figure above, I presented how the different MSL dimensions are considered during the discovery of requirements. In addition, I illustrate how these requirements are conceptualized and used to guide the design process. Finally, I show how the development and deployment efforts are implemented in the light of the MSLs. Specifically, my intention is to show how the different MSL dimensions should be considered for the requirements, design and development efforts connected to these activities. In the following subsections, I illustrate the roles of these MSLs for different aspects of the activities described in this thesis.

5.2. **CSL cases: Elaboration, Considerations, Outcomes and Evaluations**

In this subsection, I examine the educational, organizational and technological aspects of the CSL activities while addressing the different MSL
dimensions (Kohen-Vacs & Ronen, 2015). In Figure 5.2, I suggest to classify these dimensions into 3 intertwined categories.

![Figure 5.2: Categorization of the different MSLs dimensions](image)

The illustrated circles in the figure above represent three categories that overlap. In this sense, some of the MSL dimensions belong to more than one category. For example, MSL-5, which deals with ubiquitous aspects to learning resources concerns technological as well as organization categories. For instance, in the activity described in chapter 4 dealing with usability problems students were required to ubiquitously access to learning resources while being outdoors. This type of interaction also presents organizational and technological challenges.

In the next subsection, I will discuss and elaborate on the different aspects of the activities. For each of the activities, I will describe educational, organizational and technological aspects. I conclude each one of the descriptions with a paragraph describing the evaluation efforts.

### 5.2.1. Examined Aspects from Paper #3 (Case 1)

**Educational aspects:** In this activity I offer an approach for familiarizing students with usability problems through the orchestration and deployment of a CSL activity. This activity consists of five learning phases. It is supported by MoCoLeS enabling participants to interact from outdoors. The interactions conducted in this activity provided students with new opportunities to associate theoretical knowledge with practical examples experienced during informal sessions (MSL-1). Furthermore, students switch to other tasks while relying on the flow of data supported by integration between the CeLS and the MoCoLeS (MSL-8). In addition, the mentioned technologies were integrated and resulted in a flow of data enabling students to access and synthesize new knowledge.
Finally, the abilities offered by the integration of the CeLS and MoCoLeS systems enable the orchestration of an activity encompassing multiple pedagogical models (MSL-10).

Organizational aspects: Students carried out this activity in several phases each spanning along several days. They practiced phases indoors as well as outdoors while focusing on usability problems found in their real settings. These interactions were practiced while being organized in different social settings. All these aspects are mainly related to MSL dimensions dealing with encompassing personalized and social learning (MSL-2) as well as to learning across time (MSL-3). For example, in this activity, the outdoor face was conducted in small groups. A later phase dealing with voting was exercised later and was conducted individually.

The specification of these social and temporal aspects was supported by CeLS. Indoor interactions were supported by CeLS while outdoor interactions were supported by MoCoLeS (MSL-4). The integration of CeLS and MoCoLeS also enabled reuse of educational content across locations.

Technological aspects: In this activity I integrated the CeLS and MoCoLeS systems in order to support the orchestration of a CSL activity that includes interactions conducted from across locations. This integration was achieved while incorporating data from the MoCoLeS system stored in a Google Forms database into the CeLS database. The combined approach offers an advantage through the incorporation of XForm used as a generic component. These aspects are mainly technological and relate to ubiquitous access to learning resources (MSL-5) as well as to encompassment of physical and digital worlds (MSL-6). In addition, it also relates to combine the use of multiple types of devices (MSL-7).

Assessment: As mentioned in paper #3, a quantitative assessment was conducted to examine students' interactions related to the competition conducted in this activity. The practiced assessment points out to the effectiveness of the implemented tools to support the orchestration of the CSL activity. The activity included a complementary qualitative assessment used to examine students' statements. In addition, outcomes from the qualitative assessments were used to support insights gained from the quantitative assessment. The qualitative assessment included semi-structured interviews conducted with students. Students pointed out on the effectiveness of the pedagogical approach practiced in this activity. The results from these efforts provide some indications regarding the potentials of the proposed tools to support CSL.
5.2.2. Examined Aspects from Papers #5, 6 (Case 2)

*Educational aspects:* In this activity, I offer an approach to familiarize students with terms and practices related to negotiation styles. This activity consists of five phases. The activity scenario includes both formal as well as informal learning tasks (MSL-1). For example, students participated in theoretical lessons aiming to present topics related to negotiation styles. In addition, they also practiced buyer-seller situations during less formal parts of the course. As implied, during this activity students switched between multiple learning tasks relying one on the other (MSL-8). During the activity, face-to-face interactions were supported by SMS-HIT Personal Response System (PRS). Asynchronous interactions conducted elsewhere as well as orchestration this activity were supported by CeLS (MSL-10). During the deployment of this activity, these two environments were integrated while aiming on providing support for data flow. Consequently students could use CeLS while interacting on data shared from the SMS-HIT PRS and synthesize new knowledge while reusing content (MSL-9).

*Organizational aspects:* Students were required to practice this activity in several phases. They practiced each phase at classroom sessions as well as at their homes (MSL-4). These phases are mainly related to dimensions dealing with encompassing of personalized and social learning (MSL-2) as well as to learning across time (MSL-3). The orchestration and specification of these two settings was supported by CeLS. These interactions were performed in different modes with various technologies.

*Technological aspects:* Teachers and students interacted in face-to-face mode while using their mobile devices. During these interactions, students used the SMS-HIT Personal Response System (PRS) on their mobiles to capture their face-to-face interactions (Kohen-Vacs et al., 2012c; Kohen-Vacs et al., 2012d). There they declared about their presumed and owned negotiation style (MSL-7). In addition, they used their computers to interact with another system called NeSI that aimed to assist with diagnosing students' real negotiation style. Digital content generated in SMS-HIT and NeSI was integrated to the CeLS database in order to enable its later reuse (MSL-5 and 6).

*Assessment:* A quantitative assessment was practiced in order to analyze students' achievements performed during the CSL activity. In addition, a qualitative approach was practiced following the enactment of the activity in order to examine teachers’ and students' statements. This examination was was performed with semi-structured interviews with teachers and students.

These qualitative assessments indicate the perceived level of usefulness in terms of the technological approach used to support this educational activity. Students responses implied on the effectiveness of the approach practiced during this CSL activity. Specifically, they mentioned how the activity provided
powerful means to prepare them to be better negotiators that are more ready to confront such situations in real settings (related to all MSL dimensions).

5.2.3. Examined Aspects from Papers #7, 8 (Case 3)

Educational aspects: In this activity, students performed formal and informal learning (MSL-1). For example, the less formal parts included the preparation of video-clips while using the EDU.Tube authoring environment. In addition, students also experienced and assessed videos created by their peers. The entire learning experience is supported by regular and mobile instances of EDU.Tube’s player. The assessment of video clips is supported by CeLS. These environments are integrated for providing support for the interrelated parts of the activity (experiencing and assessment of video-clips). In addition, this integration also facilitated switching between learning tasks that included authoring, experiencing and assessment of video-clips (MSL-8). The flow of information enabled by the mentioned integration also provided opportunities to reuse data and perform knowledge synthesis while practicing CL strategies (MSL-9, 10).

Organizational aspects: Students practiced the activity in several phases each lasting several days. These phases they dealt with authoring, experiencing and assessments of video-clips. Students practiced each phase in and across locations while organized in different social settings (MSL-2, 3). The orchestration and specification of these two settings is supported by CeLS. In addition, students experienced and assessed video clips across various locations (MSL-4). Videos experienced indoors are supported by the regular EDU.Tube player while others experienced outdoors are supported by a mobile instance of the EDU.Tube player.

Technological aspects: In this activity, I used the CeLS and EDU.Tube systems in order to support the orchestration of a CSL activity practiced in indoors and outdoors settings. This activity was supported by the integration of CeLS and EDU.Tube components (MSL-5). The integration included EDU.Tube instances and CeLS support for students’ ubiquitous access to educational and rich media resources while using regular computers and mobile devices (MSL-6 and 7).

Assessments: I used quantitative and qualitative methods to collect and analyze data from this activity. Specifically, I used an adapted TAM questionnaire including quantitative and qualitative sections (Huang et al., 2007). In the answers to this questionnaire, students pointed on high levels of contribution in terms of the technological approach used to support this educational activity. The analysis of this questionnaire revealed the advantages and drawbacks related to environments and tools used in this activity by students to practice their educational interactions. In addition to the
questionnaire, I held semi-structured interviews with teachers also indicating several aspects related to the architectural approach and its capability to support the orchestration of this kind of CSL activity. In the interviews they asserted that they also perceived the added values of this approach enabling to easily, create, share, incorporate and use interactive video-clips in their common educational programs (related to all MSL dimensions).

In the next subsection, I provide an overview of these aspects and illustrate their use as requirements for each of the activities.

### 5.2.4. Summing up

In the last subsections, I described three CSL activities while emphasizing on various concerns including educational, organizational and technological aspects. In addition, I also addressed the assessment of these activities. These set of intertwine aspects could be used for the elicitation of requirements, to inform the design and to guide the development process of CSL activities.
Table 5.1 summarizes how these different aspects have been addressed for all cases.

Table 5.1: Aspects considered for cases of CSL activities

<table>
<thead>
<tr>
<th>Features of the activities and MSL dimensions addressed</th>
<th>Paper #3 (Case 1)</th>
<th>Papers #5, 6 (Case 2)</th>
<th>Papers #7, 8 (Case 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main aim /MSL-1, 8, 9 and 10</td>
<td>Familiarize students with usability problems</td>
<td>Familiarize students with negotiation styles</td>
<td>Familiarize students with concepts in Computer Science</td>
</tr>
</tbody>
</table>
| Practical goals of educational activities for each case /MSL-1, 8, 9 and 10 | • Capture, tag and share outdoor experiences  
• Reuse and assess outdoor experiences contributed by their peers | • Contribute students’ own perceived negotiation style  
• Enable to conduct and capture negotiation proceedings  
• Peer assess negotiation proceedings | • Author educational and interactive video-clips dealing with topics related to Computer Science  
• Consume and assess previously authored video-clips |
| Places of interactions /MSL-4                          | Indoors and outdoors | Classrooms and homes | Anywhere |
| Mobile support provided by… /MSL-5, 6 and 7            | MoCoLeS           | SMS-HIT              | Mobile EDU.Tube    |
| Stationary support provided by… /MSL-5, 6 and 7        | CeLS              | CeLS and NeSI        | CeLS and EDU.Tube  |
| Support for orchestration by… /MSL-2, 3, 4             | CeLS              |                      |                      |
| Type of Orchestrated interactions/MSL-3                 | Asynchronous      | Face-to-face and asynchronous | Asynchronous |
| Database approach/MSL-5                                 | Google XFOMS      | Data from SMS-HIT    | Data from EDU.Tube  |
|                                                        | incorporated to CeLS database | database incorporated into CeLS database | database incorporated into CeLS database |
| Integration approach/MSL-5, 6, 7                       | Integrate two approaches in order to support the design and enactment of CSL activities to be performed outdoors using mobile devices as well as indoors using stationary computers | Integrate two approaches in order to support the design and enactment of CSL activities to be performed in classrooms using mobile devices as well as stationary devices while conducting peer assessments | Integrate two approaches in order to support the design and enactment of CSL activities enabling to author and interact with educational video clips from anywhere while using stationary and mobile devices |
| Additional Concerns                                     | GPS accuracy, Interfacial challenges and orchestration | orchestration | Interfacial challenges |
5.3. The Design Process Guided by Elicited Requirements

In this subsection, I argue on how I address different aspects reflected by the MSL dimensions in the design process for the various types of CSL activities. As illustrated in table 5.1, different aspects of the CSL activities intertwinie and this should also be addressed in the design of those. Accordingly, for the design of CSL activities with various and intertwine aspects I suggest to practice a process adapted from Ravenscroft et al., (2012). This approach is presented in Figure 5.3 and it includes a process consisting of three iterations for design guided by various educational related requirements.

Figure 5.3: Spiral iterations included for the Mature Design process (adapted from Ravenscroft et al., 2012)
In the first iteration, I suggest to consider all MSL dimensions while practicing various phases focusing on:

- Prioritization of aspects as reflected in the different MSL dimensions, addressing the activities’ goals and challenges. This step aims to enable the initial design of the CSL activities while conceptualizing its educational, organizational and technological aspects.
- Exploration of experiences and constraints related to the different aspects in the CSL activity.
- Design process addressing solutions linked to the implementations of CSL activities.
- Evaluation addressing the on-going design process and targeting on how the diverse MSL dimensions were conceptualized in the previous design process.

In the following iteration, this four-step process is repeated while conceptualizing the MSLs in the same continua (Milrad et al., 2013). The last iteration aims at a final overview towards the suggestion for refined concepts for the CSL activity. In the next subsection, I discuss how this design process guided by requirements addressing aspects reflected in various types of MSLs is later used for the development and deployment efforts for the different CSL activities.

5.4. From Design Towards Deployment CSL Activities

In the previous subsection I illustrated how the MSL dimensions are conceptualized along an iterative designed-based process. In this process, I suggest to examine the various aspects of CSL activities as reflected from the MSL dimensions. Furthermore, I provide an opportunity to examine how these aspects can be combined towards the establishment of concepts for CSL activities that conceptualize different aspects as reflected in various MSL dimensions.

One of the main aspects, as mentioned previously deals with the orchestration of CSL activities supported by web and mobile technologies. The term orchestration is addressed here in its relation to Service-Oriented architectures. In this sense, services, business processes and technical
workflows are being implemented as an orchestration of (micro) services (Mayer et al., 2008; Papazoglou & Van Den Heuvel, 2007). Accordingly, the orchestration of a complete application could consist of sequenced services combined with glue code providing support for interrelated educational interactions. The glue code refers to custom-written code that connects incompatible software components.

The term orchestration was adopted and used by other researchers to address the design and management of learning interactions conducted in educational activities (Dillenbourg & Jermann, 2010).

For example, in my design process, I orchestrate services dealing with various aspects of the CSL activities. Some of these services aimed to support mobile learning, while others are adopted for more traditional forms of interactions. These services also addressed various modes of interactions including synchronous and asynchronous communication. Additionally, they address different type of generation of content. Specifically, some are adapted for text interactions while others are adapted for rich and interactive media. These services are orchestrated in a sequence of interactions reflecting educational strategies. In this case, students participating in CSL activities can consume different services sequenced and aimed to support their learning at the different phases of their tasks.

Accordingly, my proposal for an elaborated mature process is offered as an approach that combines theory and practice based on DBR (Brown, 1992; Collins, 1992; Hoadley 1992; Ravenscroft et al., 2012). This is offered following the community’s encouragement for further research considering theoretical grounding as well as practical implications related to orchestration (Hoppe, 2009; Hoppe, 2015; Roschelle et al., 2013). Ravenscroft et al., (2012) indicated that their suggested process is highly related to practical matters addressing implementation of the actual design. Accordingly, I aim to elaborate these practical aspects while recommending an approach to design and deploy future CSL activities according to the elicited requirements guided by pedagogical needs.
As mentioned and as illustrated in Figure 5.4, the realization of these activities consists of challenges concerning various and interrelated aspects addressed technologically.

![V-model diagram presenting the deployment of CSL activities](image)

**Figure 5.4: V-model diagram presenting the deployment of CSL activities**

In the figure above, I illustrate the realization of a CSL activity through a V-model diagram. The left side of this figure presents various aspects of CSL activities reflecting various MSL dimensions. The right side of the diagram presents technological environments to support orchestration. In addition, I present there middleware and Web Services as well as systems and tools used to provide technological support for educational interactions. Specifically, CSL activities are performed according to the orchestration of various educational tasks. The orchestration of interactions is specified for various settings. For instance, outdoors tasks of the usability scenario were performed in small groups while voting tasks were performed individually. Later, the set of interactions are practiced along phases of CSL activities supported by environments, systems tools and services.
The illustrated architecture presented in Figure 5.5 aims to provide different services combined for supporting various types of CSL scenarios. In the upper-right side of the figure, I describe integrated components used for supporting mobile interactions. In this example, Xforms was used to support capturing and tagging practiced in the activity dealing with usability problems.

In another case dealing with interactive video-clips, I introduce an integrated component enabling interactions with rich media experienced on regular computers and mobile devices.

This type of architectural approach aims to offer technological support for the enactment of different concepts of CSL activities. The technological support for such design relies on the incorporation and integration of technological and software services required to support the various aspects of the CSL scenarios (RQ-1). As mentioned, these aspects used to guide the design of CSL activities were conceptualized through the MSL dimensions reflecting educational, organizational and technological concerns. During my research, I used this approach to offer new ways to support CSL activities through the introduction of existing or new components. The incorporation of these components was arranged in the architecture while emphasizing generation, sharing and reuse of content according to the described requirements in the educational scenario (RQ-2). The realization of sharing and reusing of generated content is addressed architecturally in Figure 5.5. As mentioned, generation, share and reuse of content performed along the activities was supported by flow of information through the different educational services. In the first activity, students' contributions from outdoors were reused and assessed at indoors. In the second activity, face-to-face and asynchronous interactions were reused during home tasks. Finally, video-clips authored during the third activity were assessed and reused as new educational opportunities. The reuse of content in these activities relied on capabilities of data exchange among various technological environments, systems and tools. Furthermore, this data exchange enabled new options for reusing shared content as new educational opportunities. For example, in the scenario dealing with usability problems, students' interactions from outdoors were reused as new educational opportunities in peer assessments. Finally, in the figure above I present components used for supporting the orchestration of CSL scenarios. These components aimed to catalyse orchestrations that provide facilitated options for collecting and evaluating different aspects of such CSL activities (RQ-3).

The different deployments and software solutions addressed in this thesis can be presented as an overall architectural approach. This approach aims to enable teachers and students to exploit the flow of data (generation, sharing and reuse of content) along various phases of the CSL activities. For example, in the scenario dealing with familiarization of terms in Computer Science, students have authored interactive videos later used by their peers as new educational opportunities. The content contributed by the students in the activity dealing with usability problems was later shared with other peers. This content was reused by other students located in other places during peer assessments. Figure 5.5 reflects the overall architectural approach offering support for the various tasks practiced along the different CSL activities.

Figure 5.5: Overview of Proposed Architecture
The illustrated architecture presented in Figure 5.5 aims to provide different services combined for supporting various types of CSL scenarios. In the upper-right side of the figure, I describe integrated components used for supporting mobile interactions. In this example, Xforms was used to support capturing and tagging practiced in the activity dealing with usability problems.

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5.5. Contribution to the research questions

In this subsection, I describe my contributions to the research questions presented in chapter 3. I will address each of the answers while discussing the different outcomes presented in the papers. I begin this subsection while providing answers to RQs[1-3]. Later, I elaborate on these to provide an answer to the main research question.

RQ1-How to transform learning requirements into guidance addressing technological deployments aimed to support CSL activities?

In papers #4, 8 and 9, I described how I examined various types of requirements and how they were transformed into guidance enabling to design, develop and deploy software solutions to support CSL activities. In paper #4, I pointed out that the nature of these requirements are varied and address educational, organizational and technological aspects. These aspects, were address in the light of the ideas described in the chapter two addressing the orchestration of CSL activities. In one of the subsections included in chapter 3, I elaborate on aspects related to TEL requirements in the light of CSL activities. I mentioned that these requirements concern various aspects including stakeholders and their goals. In addition they address educational scenarios that reflect these goals, as well as technologies to support them. As implied, these requirements address various concerns that result in challenges related to design, development and deployment of technologies. The different activities described in papers #3, 5, 6, 7 and 8 illustrate how some of these challenges have been tackled in the light of three different CSL activities. In order to cope with these challenges, I used the MSL dimensions proposed by Wong & Looi (2011) in order to associate different requirements related to various concerns of CSL activities. Also earlier in this chapter, I presented a categorization of MSLs into 3 major groups reflecting educational, organizational and technological aspects. Later these categorized requirements were addressed in the design process used for the development and deployment of the different software solutions. Consequently, the design process is considered as a crucial step that influenced all later efforts towards the deployment.

The third chapter of this thesis includes a subsection discussing the DBR approach (Research Collective, 2003) and its implications for my work. There, I discussed various characteristics of the design process that included iterations practiced during development and research. One of the main challenges with such process concerns the variance of requirements concerned with CSL activities. Accordingly during these efforts, I put special emphasis while examining and considering the adaptation of the process suggested by Ravenscroft et al., (2012) for designing concepts for CSL activities. Specifically, this was considered in order to prioritize and examine various concerns related to these activities. In the following steps of my efforts, I
adopted and elaborated this approach in order to assist with the prioritization and examination of concerns as reflected from MSLs and related to CSL activities. Later, these examinations were introduced in the design process that is evaluated and refined. This adaptation is presented as an approach that offers alleviation with complex design of CSL activities requiring to consider various types of aspects.

Papers #8 and 9, further emphasize the challenges with the mentioned design process while further elaboration on these requirements. Furthermore, in these two papers, I focus on the importance of these requirements towards their transformation into guidelines for designing, developing and deploying software technologies to support CSL activities.

RQ2-How to design and deploy web and mobile tools that enhance flow, share and reuse of learner generated content along the different phases of CSL activities?

The cases presented in papers #3, 5, 6, 7 and 8 describe the orchestration of CSL activities while relying on software tools enabling to enhance the flow, share and reuse of digital content generated by teachers and students. In one of the subsections of chapter 2, I elaborate on topics related to the orchestration of seamless learning activities. In the previous subsection of this chapter, I further address this term in relation to Service-Oriented architectures (Mayer et al., 2008; Rosen et al., 2012). Accordingly, I proposed there, an architecture that included various components offering different types of services that could be sequenced and organized to support the flow of a CSL activity. The activities presented in the mentioned papers #3, 5, 6, 7 and 8 included various learning tasks orchestrated along different phases. These tasks include different modes of interactions practiced across various settings and supported by web and mobile tools. The architectural approach proposed in this chapter offers to support these interactions by various and integrated components. The environments, systems and tools as presented in the mentioned papers, were designed, developed and deployed while having in mind their integrations aimed to support the mentioned dataflow. Accordingly, the technological integration addressed data that was formatted, shared and reused by various tools. These aspects were addressed in the mentioned papers a well as in papers #4 and 9. In addition, these efforts concern architectures that included integration of various components enabling data exchange between different tools. The different features and functionalities of the aforementioned implementations served as the basis for the proposed general architecture. It aims to offer a comprehensive support for generation, share and reuse of content interacted by web and mobile tools by teachers and students along the scenario of the CSL activity. In addition, the suggested architecture is flexible and could be expanded in order to address new types of interactions incorporated in future CSL activities.
RQ3-Which methods should be used in order to assess CSL activities and the tools deployed and exploited for supporting them?

The cases described in papers #3, 5, 6, 7 and 8 address various concerns that are typical to CSL activities. As mentioned in this thesis, the nature of CSL activities concern with challenges related to interactions sequenced along different phases and performed across locations (MSL-3 and 4). These concerns present implications on the evaluation of CSL activities. Specifically, the evaluations of such activities consist of using data generated shared and reused across locations and along its phases. In addition, it also consists with evaluation of the contexts in which these interactions took place.

In order to trace and evaluate the different learning experiences in these activities, I used blended methods including quantitative and qualitative approaches. These methods aimed at examining data in the light of the special nature of CSL activities as reflected from its special aspects emphasized in MSL-2, 3 and 4. Specifically, I examined the interactions practiced in these activities in the light of the social settings in which they were performed. In addition, I examined the locations from which these interactions were conducted. For example, in the activity dealing with usability problems, I examined data interacted by students while focusing on aspects beyond the contributed content. Furthermore, this examination focused on the nature of their groups as well as on the time and location that the usability problem was tagged and shared. For such type cases, the actual quantitative examination of interactions conducted by teachers and students in real settings may provide a partial evaluation of the examined activity. As mentioned, the special nature of CSL activities include educational tasks that could be conducted in various conditions influencing the nature of the experience. Accordingly, I introduced into my research efforts semi-structured interviews. These interviews aim to gain additional information that cannot be collected using quantitative methods. Specifically, quantitative data may lack information concerning additional conditions that may impact the nature of experiences in CSL activities. In the case dealing with usability problems, semi-structured interviews revealed aspects that were not reported by students in their regular tasks performed along the activity. For example, aspects related to the social dynamics and other individual insights experienced outdoors were not captured in the activity task but were retrieved during the interviews. In addition, information from interviews was used in order to validate quantitative information. During these semi-structured interviews, participants were requested to recapture social situations, moments and locations in which these activities were provided. Practically, in all the mentioned papers, teachers and students were interviewed while seeking for their insight about various aspects experienced along the phases of the CSL activities. These interviews also aimed to provide insights about technologies used to support the activities. Specifically, they were conducted as I aimed on
refinement related to the design of these technologies. Accordingly, the elaboration on the process as suggested by Ravenscroft et al., (2012) addresses the design of these technologies for supporting complex CSL activities. Later in chapter 4, I present some of the challenges related to the deployment of such activities, including their organizational aspects and the ways in which web and mobile tools were used to alleviate them (MSL-5,6 and 7). Accordingly, a special emphasis was put on the role of technologies while supporting various types of interactions practiced in these activities. For example, interviews conducted following to the activity dealing with usability problems addressed the ways that students used mobiles to interact from outdoors in situations not always predicted by the teacher. In other interviews conducted following to the activity dealing with negotiation styles, teachers and students addressed the used technologies as well as the benefits from their integration. Finally, the interviews conducted following to the activity dealing with familiarization of concepts in Computer Science addressed students elections of a technology used for interacting with rich media. In all these examples, semi-structured interviews, were used to gain insights about how these technologies were used and how they could be better exploited in real life settings. In this sense, insights provided in these interviews are important in the light of DBR process where researchers intervene, consider and implement their concepts in natural settings (Brown, 1992; Collins, 1992; Hoadley 2002). Accordingly, I suggest to use the Spiral Model as illustrated in Figure 5.3 for a design process considering technological tools for concepts of CSL activities. In this sense, it should be mentioned that In paper 8, I presents the use of a TAM questionnaire enabling to examine additional technological aspects that include the acceptance of these tools among teachers and students (Huang et al., 2007).

As mentioned in chapter 3, these research questions reflect a major research aim dealing with the following question:

*How to best design systems and tools to support students during the enactment of collaborative seamless learning activities and to provide teachers with artifacts to design and assess those?*

This main research aim reflects three major aspects. The first aspects is related to the design process for CSL activities. As mentioned in the previous answers, the design process should concern educational, organizational and technological aspects as introduced in the chapter dealing with theoretical perspectives. Consequently, this design process should address the special nature of CSL activities requiring technological means to support them. Specifically, the special nature of these activities consists on enactments conducted across location and time. In addition, these enactments also address various types of content interacted along the phases of the CSL activities. All these mentioned aspects require technological support enabling teachers and
students to interact in various modes and across locations along phases of the activities.

Finally the interactions and the tools used to support CSL activities, were targeted in my efforts also addressed educational aspects of the activities as well as technologies used to support them. These comprehensive set of aspects are suggested to be considered while using the Spiral Model as illustrated in Figure 5.3 for the deployment of future and innovative concepts for CSL activities.
6. Conclusions

In this chapter, I summarize the outcomes of my research. I begin first by contextualizing my research in order to position myself in relation to similar efforts. I then continue by presenting my scientific contributions and proceed thereafter by discussing some of the limitations of my work. Finally, I conclude and describe possible directions for future research in this field.

6.1. Contextualization of My Research Efforts

In the previous chapters, I presented my research efforts dealing with elicitation of requirements and design approaches used to guide the design, development and deployment of CSL activities. As mentioned, these activities requiring teachers and students to interact in different modes while using regular and mobile devices. The deployment of these activities is moreover aligned with a wider educational trend recognizing the potential benefits of mobile technologies used for educational purposes (Cheon et al., 2012; Khan et al., 2015; Lu et al., 2014). Accordingly, I present a contextualization of my research in order to position myself in relation to similar efforts. I present this while elaborating on Gartner's Hype Cycle and development of mobile learning (Laru, 2012).
6.2. Summary of Contributions

In this thesis, I addressed ways to best design systems and tools to support students during the enactment of CSL activities. I also addressed the need to provide teachers with artifacts that will assist with design and assessments of these activities. As mentioned previously, the specific research questions that have been explored:

- **RQ1**—How to transform learning requirements into guidance addressing technological deployments aimed to support CSL activities?
- **RQ2**—How to design and deploy web and mobile tools that enhance flow, share and reuse of learner generated content along the different phases of CSL activities?
- **RQ3**—Which methods should be used in order to assess CSL activities and the tools deployed and exploited for supporting them?

The summary of contributions discussed in the next paragraph addresses these research questions. This thesis identifies the central role of the MSL dimensions for the elicitation of requirements (RQ-1). Later, these requirements are used to guide the design and development of technologies aiming to support CSL activities (RQ-2). The design approach suggested in the previous chapter was considered during the adaptation of existing and new developed web and mobile tools used to support various types of interactions conducted in these activities (RQ-2). Specifically, I propose and develop a software architecture including various integrated components enabling to generate, share and reuse elements.

Figure 6.1 locates my efforts (marked by white circles) along other similar research efforts.

Figure 6.1: Contextualization of my research efforts

In the figure above, I positioned the efforts described in paper #3 (Case 1) next to the research of Chan et al. (2006). Chan and colleagues address the term one-to-one TEL while examining its affordances in the light of mobile technologies. I consider this case as associated with a research phase addressing practitioners' enlightenment in relation to mobile learning (Kohen-Vacs et al., 2011). In this case, I presented a deployment of a CSL activity offering to support students' interactions during a collaborative learning activity practiced across contexts. Accordingly, I designed, developed and integrated various technologies to support students' interactions practiced during different phases of a CSL activity. Case 2 (papers #5, 6) was carried out guided by the MSL dimensions suggested by Wong's and Looi's (2011). I elaborated on the MSL dimensions in two of my publications (Kohen-Vacs et al., 2012c; Kohen-Vacs et al., 2012d). In these efforts, I designed, developed and integrated various technologies for facilitating wider engagement by students in more traditional classroom sessions. This activity consisted of several phases including a phase in which students used their mobile devices to support face-to-face classroom interactions. These classroom interactions provided students with the opportunity to contribute information dealing with their presumed negotiation styles. In the other phases, they reused the information from these interactions contributed by their peers while being at their homes. These deployment and
research efforts were exercised while having in mind an early exploration and publication that addresses the elicitation of TEL requirements (Kohen-Vacs et al., 2012b). Case 3 dealt with the design, development and deployment of an integrated technological solution enabling students to author interactive video-clips that could later be used anywhere during further phases of the activity (Kohen-Vacs et al., 2013; Kohen-Vacs et al., Submitted). The elicitation of TEL requirements for the mentioned activities is described in a later book chapter (Kohen-Vacs & Ronen, 2015). In this publication, I focus on an approach to elicit requirements based on the mentioned MSL dimensions (Kohen-Vacs & Ronen, 2015). This approach is guided by requirements as reflected from the mentioned MSL dimensions. In addition, my deployment efforts also offer new opportunities to evaluate and refine these activities. In the following subsection I provide a summary of my contributions related to the research efforts conducted in this thesis.

6.2. Summary of Contributions

In this thesis, I addressed ways to best design systems and tools to support students during the enactment of CSL activities. I also addressed the need to provide teachers with artifacts that will assist with design and assessments of these activities. As mentioned previously, the specific research question that have been explored:

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The summary of contributions discussed in the next paragraph, addresses these research questions. This thesis identifies the central role of the MSL dimensions for the elicitation of requirements (RQ-1). Later, these requirements are used to guide the design and development of technologies aiming to support CSL activities (RQ-2). The design approach suggested in the previous chapter was considered during the adaptation of existing and new developed web and mobile tools used to support various types of interactions conducted in these activities (RQ-2). Specifically, I propose and develop a software architecture including various integrated components enabling to generate, share and reuse
content during the different phases of the CSL activities (RQ-2). In addition, I developed and implemented software tools that enable the creation and collection of content as well as means to evaluate the outcomes of the different learning activities (RQ-3). As mentioned, the realization of the activities also relied on my developmental efforts addressing the CeLS environment used to support the orchestration of CSL activities. My efforts also addressed requirements for supporting various modes of students’ interactions. These interactions include face-to-face (SMS-HIT) as well as tagging and sharing of outdoor experiences (MoCoLeS). In addition I also addressed interactions with rich media (EDU.Tube). All these interactions were orchestrated and stored in the CeLS environment used for supporting the flow, sharing and reuse of content in phases interacted from across settings. Finally, the different pieces of content were used for evaluating the different activities (RQ-3). Additional information was collected by conducting interviews and focus groups with teachers and students. These evaluations aim to enable examination, refinement and improvement of CSL activities based on their actual enactment in real educational settings. The discussed contributions in this subsection could be summarized as follows:

- **Contribution #1:** Elicitation of educational requirements focused on different and interrelated MSL dimensions reflecting aspects of CSL activities;
- **Contribution #2:** Development of an elaborated approach to be used for the design and deployment of tools to support and enact CSL activities. These efforts were guided by the results emerging from the contribution above;
- **Contribution #3:** Proposing an initial architectural approach to support and evaluate new concepts for CSL activities.
6.3. Limitations

As with every research activity in any scientific field, there are a number of limitations that should be mentioned. The limitations of the research activities carried out in my research relate to both educational and technological aspects. These limitations are discussed from different perspectives including the elicitation of requirements, the design process, development and the deployment efforts.

From an educational perspective, the activities practiced were deployed with students attending undergraduate and graduate academic degrees. The papers in this thesis do not present experiments conducted with elementary school students. In this sense, it should be mentioned that the deployment of CSL activities for younger participants may require some adaptation modifications along the deployment process. These modifications may be needed for the elicitation of requirements as well as for the design, development and deployment of CSL activities aimed to be adapted by younger participants. Specifically, these modifications may be considered in terms of modified educational interactions offering better scaffolds that are more adapted for new type of participants. Technologically, these scaffolds should be offered through convenient and more acceptable tools familiar to the new type of participants. Finally, there are also possible limitations in terms of the evaluation methods known to the community of researchers. In this case, the limitations concern with how to collect and analyse the vast amount of data generated in such CSL activities given the diverse settings and learning situations that are not under the teacher’s control.

6.4. Future Research Efforts and Directions

As mentioned in previous chapters, the content generated by teachers and students along the CSL activities was later shared and reused in various settings. These settings were specified according to the nature of the educational situations in which the interactions took place. In addition, these scenarios included rules addressing the social settings in which these activities were carried out. The realization of these rules was included in the scenario of the CSL activities. The mentioned activity addressing familiarization of students with usability problems could be used as an example to illustrate such scenario. Specifically, the first phase of this activity was set to be performed at outdoors in small groups. In the following phase, students were required to select the best artifacts contributed by each of the groups. The interactions in this phase were set to be performed at indoors in with the same grouping that participated in the activity conducted outdoors. The following phase dealt with assessments of artifacts contributed by each group. This interaction was set to be conducted
individually, without specifying a location. These type of activity reflects a flow of information among individuals and groups interacting from and across locations. In addition, these activities could be offered as appealing opportunities for students across levels. This example of CSL activity could be further elaborated and may include design, development and deployment efforts enabling use of CSL activities by new types of participants. In addition, these activities could be integrated to social media environments commonly used by many teachers and students. Finally, these social media environments could be used to support better analysis of interactions introduced along CSL activities.

Accordingly, and as mentioned in the previous subsection, these activities could be considered and used by wider populations of primary and secondary school teachers and students. In such cases the design and development of CSL activities should be adapted while aiming for technological environments suited to younger learners. Such deployment practiced with new participants implies on necessary adaptations in terms of the elicitation of requirements. Accordingly, further steps including the design, development and deployment would be also impacted.

One of the main specifications included in CSL scenarios addresses social grouping of students aiming to participate in such type of activities. These social settings can be considered in future research efforts also in the light of teachers and students that interact in various social media environment. Specifically, in later years we have witnessed how social media environments becoming more prominent for both teachers and students. Accordingly, one other possible direction for my future research efforts could focus on how to exploit well accepted and generic social media environments to be incorporated in the orchestration of future CSL activities. For example, an activity dealing with authoring and assessment of interactive-videos could rely on social settings specified in social media environments. Furthermore, interactions with such environments, could later offer facilitated options to implement advanced analytic features.

Finally, other possible direction for future research direction addresses the combination of CSL activities with new features dealing with learning analytics. This direction is considered while aiming to provide these activities with better adapted and more meaningful educational interactions introduced to CSL activities. Specifically, this direction offers options to analyze data that is formulated according to more recent specifications such as xAPI sentences (Kitto et al., 2015). Finally, these features could be later used for evaluation, refinement and establishment of new concepts for innovative CSL activities.
refinement and establishment of new concepts for innovative CSL activities. (Kitto et al., 2015). Finally, these features could be later used for evaluation, formulated according to more recent specifications such as xAPI sentences. Specifically, this direction offers options to analyze data that is adapted and more meaningful educational interactions introduced to CSL. This direction is considered while aiming to provide these activities with better combination of CSL activities with new features dealing with learning analytics.

In environments, could later offer facilitated options to implement advanced specified in social media environments. Furthermore, interactions with such authoring and assessment of interactive-videos could rely on social settings orchestration of future CSL activities. For example, an activity dealing with accepted and generic social media environments to be incorporated in the direction for my future research efforts could focus on how to exploit well prominent for both teachers and students. Accordingly, one other possible later years we have witnessed how social media environments becoming more and students that interact in various social media environments. Specifically, in these social media environments could be used to support better analysis of interactions introduced along CSL activities. Finally, these social media environments could be considered and used by wider populations of primary and secondary activities should be adapted while aiming for technological environments suited younger learners. Such deployment practiced with new participants implies opportunities for students across levels. This example of CSL activity could be locations. In addition, these activities could be offered as appealing of information among individuals and groups interacting from and across individually, without specifying a location. These type of activity reflects a flow further elaborated and may include design, development and deployment efforts enabled use of CSL activities by new types of participants. In addition, these activities could be integrated to social media environments commonly used by many teachers and students. Finally, these social media environments could be used to support better analysis of interactions introduced along CSL activities.


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