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Using Cloud Services to Develop Learning Scenarios from a Software Engineering Perspective

Marc Jansen
(Ruhr-West University of Applied Sciences, Mülheim an der Ruhr, Germany
marc.jansen@hs-ruhrwest.de)

Lars Bollen
(University of Twente, Enschede, The Netherlands
l.bollen@utwente.nl)

Nelson Baloian
(Computer Science Department, Universidad de Chile, Santiago de Chile, Chile
nbaloian@dcc.uchile.cl)

H. Ulrich Hoppe
(University of Duisburg-Essen, Duisburg, Germany
hoppe@inf.uni-due.de)

Abstract: The term “Cloud Computing” does not primarily specify new types of core technologies but rather addresses features to do with integration, inter-operability and accessibility. Although not new, virtualization and automation are core features that characterize Cloud Computing. In this paper, we intend to explore the possibility of integrating cloud services with educational scenarios without re-defining neither the technology nor the usage scenarios from scratch. Our suggestion is based on certain solutions that have already been implemented and tested for specific cases.

Keywords: Cloud Computing, Cloud Services, Learning Scenarios
Categories: C.2.4, K.3.1

1 Introduction

Cloud Computing provides a set of ubiquitous services that are often used to overcome certain limitations of mobile devices, desktop computers or server systems, especially to improve accessibility and interoperability. The set of Cloud Computing services is usually subdivided into at least the three following parts [Chappell 2008]:

1. *IaaS - Infrastructure as a Service*: Virtual provision of computing power and/or memory. A prominent example of an IaaS service is the Amazon WS service.
2. *PaaS – Platform as a Service*: Provision of a runtime environment, like application servers, databases etc. In this area, Google's App Engine is probably the most prominent example.
3. *SaaS – Software as a Service*: Provision of usually browser based applications that can directly be used. Here, Google Docs or the Customer Relationship Management software of *salesforce.com* serves as examples.

One aspect that is common to these three types or levels is the high degree of automation that is pursued by such kinds of Cloud Services. On the IaaS level, Cloud Computing can be understood as virtualization technology along with a high degree of automation, whereas PaaS provides a flexible way for the deployment of applications and SaaS is able to provide applications directly to the end-user, again, in a flexible and highly automated way.

In this paper, we discuss possible contributions of Cloud Services to new forms of technology-enhanced learning and teaching. The term Cloud Services itself will be explained later on in more detail. Starting with an abstraction of the common understanding of Cloud Computing, transferring the abstracted features to other prominent internet services like, e.g., Twitter, Facebook and GoogleMaps (which we see as specific instances of Cloud Services in the context of this paper), we argue that in the context of learning scenarios a wider definition of Cloud Services is needed to encompass possibly relevant new developments. Furthermore, this paper presents an architecture that allows the flexible usage of services that belong to the extended definition of Cloud Computing. We describe four examples of learning scenarios that build upon the presented architecture to demonstrate how these services facilitate innovative aspects of technology-enhanced learning scenarios. Finally, an outlook for future development of this understanding of Cloud Services is presented.

2 An Alternative Perspective on Cloud Services for Learning Scenarios

In abstraction, Cloud Computing increases the flexibility of modern applications while at the same time improving security aspects such as availability, data storage or communication. Furthermore, one major aspect in Cloud Computing scenarios is the accessibility of the provided services through a standardization of interfaces.

With respect to learning scenarios, a different perspective to these abstracted features of Cloud Computing services (referred to in this paper as Cloud Services) offers a new understanding of prominent services like Twitter or Facebook. These Cloud Services can then be used as entry points for value-adding functions both in formal and informal learning settings, remote and co-located situations and in synchronous or asynchronous scenarios. On the one hand using such services allows getting into contact with students on internet platforms where they spend a large amount of their time [Jansen et al. 2012], and on the other hand, to use off-the-shelf software [Pettersson & Vogel 2012], which saves implementation efforts and development time, but allows for using contributions from the students via these different Cloud Services.

3 Different Categories for Cloud Services for Learning Scenarios

This section describes four major categories that Cloud Services can be subdivided in. It is important to mention that the following categories are not disjoint, so that a given Cloud Service can belong to more than one category. Nevertheless, having a common understanding of these four categories might help to foster the communication and discussion of future development of both, Cloud Service themselves and applications using provided Cloud Services.

3.1 Category 1: Cloud-based Communication Services

Cloud-based Communication Services can facilitate computer-mediated communication between learners in the context of collaborative learning scenarios. This can either be in co-located or remote modes, as well as in synchronous and asynchronous learning scenarios. Prominent examples of such Cloud-based Communication Services are the Facebook Chat, the use of Twitter, for sending small messages to groups, and discussion/support networks like stackoverflow.com, for discussing special topics like technology related inquiries.

The implemented communication can be of various nature: with respect to usual chat tools, e.g., the Facebook Chat, the communication will be among a group of people that know each other (at least to some extent) who (virtually) meet on a frequent basis on the given platform. This kind of communication is not necessarily limited to a certain topic. On the other hand, in social networks like Twitter, the messages are shared within a group of people interested in messages that one person is posting. These groups are usually referred to as “followers”. The communication here does not necessarily happen in the way that everyone in the group can read what everyone else writes, but everyone in the group (that is every “follower”) can read what the person they are following has written, but not what other “followers” reply. In the third example of discussion/support networks (*stackoverflow.com*), the communication is completely open. Everyone can answer a question and can also reply to answers from other participants. Here, usually, the participants in the discussion do not know each other and the group is formed informally by people just taking part in the discussion. This kind of communication could be characterized as topic-centred (rather than person-centred).

Cloud based Communication Services are an interesting resource to be used in learning scenarios. One hand they can be used for fostering the communication among a group of learners and on the other hand for a later-on analysis of the communication in order to reflect about the learning process. They are readily available and do not require specific extra implementation or installation efforts.

3.2 Category 2: Cloud-based Repository Services

This category of Cloud Computing based services allows its users to build up repositories by storing and retrieving objects in the Cloud. Typical examples of such services are Dropbox or Amazon Simple Storage Service (S3). E.g., Dropbox provides facilities to store any file in an external storage hosted in the Cloud. Here, Dropbox provides a rich integration in the common operating systems (Windows, Linux, MacOS X, etc.) so that storing a file in the Cloud is as easy as storing the file on a local harddisk.

Similarly, Amazon S3 also provides the possibility to store files in the Cloud. In contrast to Dropbox, the major focus of Amazon S3 is not so much on the consumer market, but the service is more targeted towards users of other Cloud Computing Services offered by Amazon, e.g., users of Amazons IaaS infrastructure can store harddisks of virtualized servers easily in an S3 data structure. A rich user interface integration, as known from Dropbox, is not yet available for Amazon S3.

Other examples of Cloud Computing based Storage Services would be specialized storage solutions, e.g. for videos (like Vimeo or Youtube) or photos (like Flickr or Instagram). Here, the major difference between these topic related storage solutions and the more general solutions mentioned before is on the one hand, the specialization, for a certain type of files (like videos or photos). On the other hand, these highly specialized storage solutions are usually enhanced with asynchronous communication mechanisms such as commenting or discussion functions, e.g., to discuss an uploaded video or photos. As mentioned before, this is an example that the four different categories may overlap (here with the first category, providing also communication channels).

Nevertheless, the major added value of Cloud-based Repository Services is on sharing content among a potentially larger number of users. This makes these kind of services especially interesting for learning scenarios, e.g., for building Learning Object Repositories (LOR) [Neven, Duval 2002], so repository in which learning outcomes can be stored in order for being re-used either as input for new learning scenarios or as a bases for discussion and analysis of certain learning activities.

3.3 Category 3: Cloud-based Production Services

The third category of Cloud based Services, the Cloud based Production Services, focus on the generation of new content and/or information enrichment. Here, we would particularly distinguish “rich” production from the simple provision of small textual input as it is already provided in communication tools. The web-based application MindMeister for producing mind maps is an example for such a service. Often, production services draw on services of the first two categories in order to gather and re-arrange information from different sources together into a new application. As a user interface, Cloud-based Production Services often appear as so-called mashups. A mashup is an application that retrieves data from different sources and combines them into a new application, usually focused on a new user group. A nice example of such a mashup can be found in [Rizzardini, Linares et al. 2012].

The major clue with this kind of Cloud-based Services for learning scenarios is on the one hand the re-use of already implemented applications and the data that this applications provide, and on the other hand, the high degree of integration of different applications, that this approach allows. The combination of these, allows for the production of new data, together with a much differentiated view on this data provided by the different applications that are used in order to generate the new data. Here, of course, the combination of the formerly mentioned two categories supports the process of production of rich data within activities of certain learning scenarios.

3.4 Category 4: Cloud-based Processing Services

The last category of Cloud based Services, the category of Cloud based Processing Services, allows to investigate/process data, especially when this data comes in huge datasets. A typical example of this kind of service would be the Amazon Elastic Map and Reduce service. This service provide a core implementation of the Map-and-Reduce, classical divide and conquer algorithm introduced by Google in [Dean, Ghemawat 2004], that allows to easily analyze huge datasets with a minimal implementation effort.

Cloud-based Processing Services allow for the analysis of the learning activities either in real-time in order to actively support the learner during a given learning activity, or afterwards in order to understand benefits and problems the learner gained/had performing the learning activity in the sense of separate re-usable and configurable analytics services. Therefore, Cloud based Processing Services have the potential to increase the efficiency of learning activities/scenarios by analyzing the learning outcomes and the steps that a certain group of learners takes.

Of course, the data provided by the analysis is often provided by Cloud-based Production Services, Cloud-based Communication Services and/or Cloud-based Repository Services. Therefore, the last category often exploits data provided by the other three categories.

4 A Software Engineering Perspective on Cloud Services for Learning Applications

The reuse of software components is one of the building blocks of modern Software Engineering approaches. In [Pettersson & Vogel 2012] the authors state that the term “re-use” can be interpreted somewhat differently with respect to Software Engineering approaches for the field of Technology-Enhanced-Learning (TEL). On the one hand, there is the re-use of content, which seems to be fairly well accepted. On the other hand, there is the re-use of both single software components as well as the re-use of established and approved architectures. In contrast to the re-use of content, these two more technical aspects of re-use are not yet well accepted or used. Here, the usage of cloud services might help to either increase the re-use of single software components, e.g., provided as Web Services, and the re-use of established and approved architectures.

Web Services, as one of the building blocks for modern Cloud Computing environments, implement the idea of providing re-usable software components. One view to Web Services is that the major idea of Web Services is to provide re-usable software components that are made available through a set of standardized protocols. These protocols support consumers of these Web Services through the complete development cycle from finding a particular service (e.g., in a UDDI repository), accessing the description of the service interface (e.g., described in WSDL) to consuming the service (e.g., by using protocols like SOAP or REST). Therefore, the provisioning of Web Services in itself already provides a big opportunity for re-using single software components and by using the mentioned standardized protocols, the re-use of these kinds of software components is even possible beyond the borders of a single organization.

This is particularly interesting for learning scenarios, since in this area, there are not many commercially oriented organizations or research groups. Instead, the different players are willing to share their content as well as their developed services among each other in order to foster collaboration among different learning communities. Of course, when it comes to content re-use, aside from the technological problems that are fairly easy to solve by using Web Services, other problems such as the ownership of the resulting learning outcomes and questions about the right to re-use these learning materials arise, as, e.g., discussed in [Giemza, Verheyen et al. 2012].

From an architectural point of view, due to their possibility of re-use Web Services allow a completely new approach to the architectural development of the resulting software, and of course, also for the resulting learning applications. Here, the development of new software can be performed based on an architecture that is usually referred to as a Service-Oriented-Architecture (SOA). The building blocks of a new software developed based on this architecture are services (in our context usually Web Services). The major idea of a SOA is to build new software based on a number of already existing services. The general task that a piece of software should fulfil is usually split up into different subtasks that are performed by a number of different, and usually already existing, services. Later on, after completing all the subtasks, the results of these subtasks are aggregated into the solution of the general task. The combination of the different services that fulfil the subtasks and the combination of the results if often referred to as “orchestration” and the produced code is often referred to as “glue code”. Using a SOA based architecture nowadays changes completely the usual software development process from having to write every piece of code (even with the help of already developed API’s) that is necessary in order to fulfil the task at hand, to finding services that support the developer in solving the special task, the orchestration of these services and providing/implementing the glue code that allows to solve the current task. In this sense, the Cloud Computing paradigm itself provides already a new approach for the architecture of learning scenarios.

Cloud services may also lead to an enrichment on the content level: The matching of user (learner) needs to available materials may draw on existing learner profiles, e.g. in social or professional networks, in addition to content related resources, possibly using semantic web technologies. The added value over conventional learning metadata approaches would be the openness and free connectivity of the environment.

From a technological point of view, Cloud Computing could be seen as the next consequent development step from a SOA to an architecture that does not only allow the re-use of content and services (in the terms of single steps in a process), but additionally the re-use of computational resources. E.g. in an SaaS scenario a complete software stack would be re-used, which is pretty close to the idea of a SOA where basically single services are the major goal of re-use. On the next level, in a PaaS scenario, not single services are the target for re-use, but the infrastructure for running these services can be shared by different consumers. Last but not least, IaaS scenarios allow for re-using infrastructure on the lowest technical level, e.g., the re-use/sharing of computational resources (like virtual servers), network resources and/or storage resources. Hence, Cloud Computing allows to overcome the limitations that usually exist within SOA’s, e.g., that the re-use is still limited to the content and/or the services in terms of process steps, and allows to provide re-use for the complete stack from single software services to the technical layer of the network and the storage.

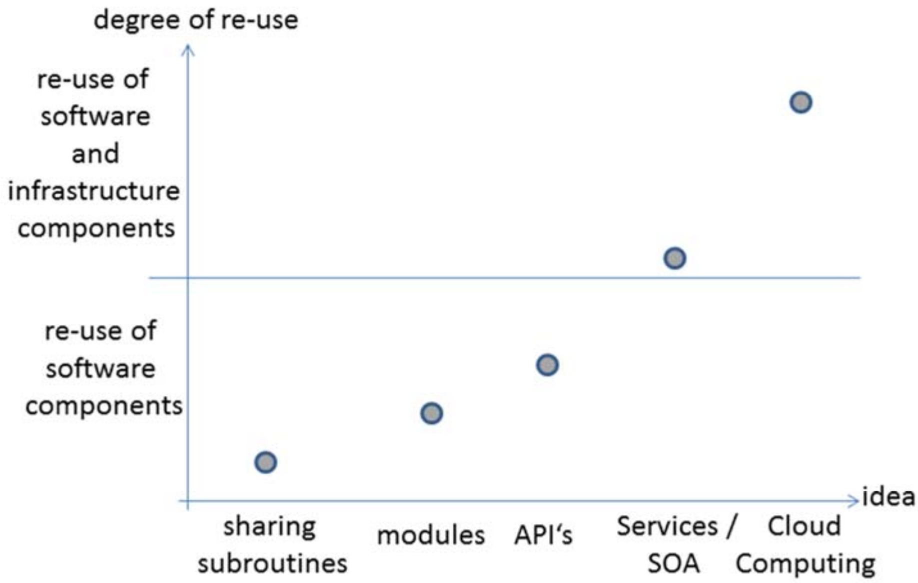

Figure 1: Different degree of re-use with different software engineering approaches

Figure 1 shows the idea of understanding Cloud Computing as the consequent next step of software engineering in order to extend the re-usability to the level of not only re-using software components but also infrastructure components.

5 Example Learning Scenarios using Cloud Services

Keeping in mind the previously mentioned benefits of Cloud Computing, services such as Twitter, Facebook and GoogleMaps provide similar benefits to computer-supported learning environments, e.g., by increasing flexibility, availability and the accessibility of services and content through standardized methods. Therefore, services as those described above can also be understood as cloud services and can then be used in learning scenarios in order to exploit the described benefits of Cloud Computing based services, integrating cloud services as input channels.

In this section, we will describe two different approaches to implement computer-supported learning environments that make use of and integrate Cloud Computing services. Our proposal does not primarily aim at defining new cloud environments for education, but to connect specific educational environments around virtual or face-to-face classroom scenarios with existing Cloud Services. One approach, called "Mobile Contributions" (MoCo) stresses the use of various cloud services as data input mechanism for the system in order to increment its accessibility. The second one called “Antenna Planning Learning” (SiPlAnt for its name in Spanish) stresses the approach of combining various existing cloud services to develop a new system.

At the end of each example, we will classify and discuss the examples along the categories from section 3.

5.1 Integration of Mobile Contributions

The basic idea behind "MoCo" ("Mobile Contributions") is to create a software architecture and to define application scenarios to allow learners to create and send short contributions to actively participate in educational activities. To this end, we envisage a system that integrates various "input channels" with a flexible storage engine and visualization frontend.

A technical infrastructure to support this is outlined in Figure 2. The major task performed by this infrastructure is to provide a certain abstraction for the messages received through the different input channels, store these messages and later allow a flexible message visualization to be used in learning units.

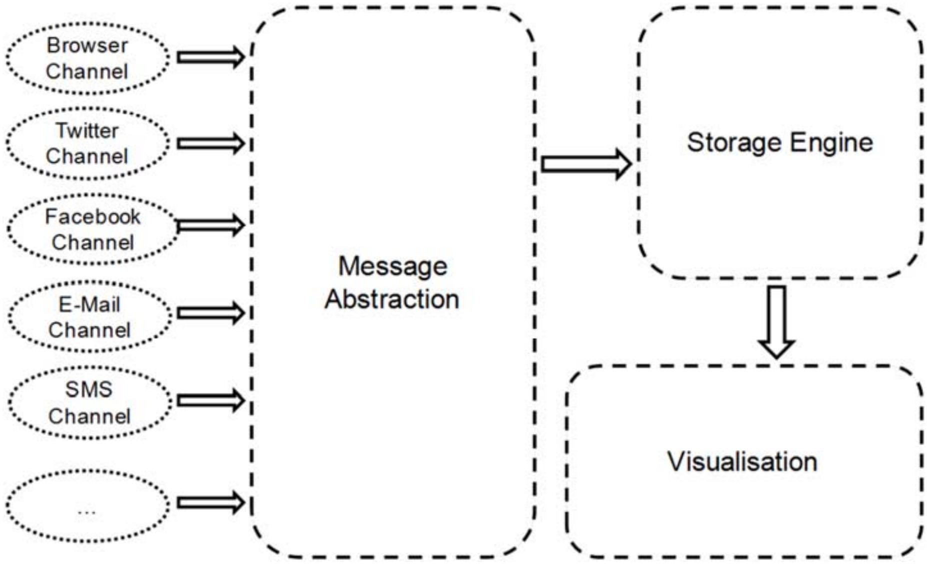

Figure 2: Architecture to support multichannel input

This architecture is a generalization of an approach that has been implemented and tested with certain specific cases [Bollen, Jansen et al. 2012]. In the sequel, we describe some example scenarios illustrating our understanding of the benefits that Cloud Services might bring to learning scenarios. Here, we see advantages in both, formal and informal learning settings. A differentiation can additionally be made with regard to synchronicity – contents can be generated and directly used in class, e.g., to support face-to-face scenarios, to replace moderation cards and flipcharts in individual and group work. Contents can also be generated in class and used in a future session.

One particular strength of integrating this kind of cloud services is that in addition to supporting and enabling the scenarios described here, it also supports seamless transitions between those scenarios. For example, it is intended to motivate the learners in informal learning scenarios, to contribute and make use of this content in a face-to-face classroom situation in a fully integrated way. The following subsections describe four scenarios which can be carried out with the help of the mentioned Cloud Services in more detail. Our basic approach is to use existing services to create, collect and visualize students' contribution in various educational settings and scenarios. These scenarios build upon established learning and teaching scenarios; their realization with the help of the before-mentioned Cloud Services and the proposed architecture add flexibility in time, space, synchronicity and re-usability of technology and data.

5.1.1 One-Minute Papers

One-minute-papers are a flexible and efficient way of collecting feedback from small and large groups of learners in seminars or lectures (also refer to, e.g., [Angelo, Cross 1993; Chizmar, Ostrosky 1998; Stead 2005] for details and empirical findings on the method). Students are handed a piece of paper with questions they have to answer in (typically) one minute.

Example questions may focus on the contents of the seminar lesson, e.g., "What did I like?", "What was new to me?", "What do I consider important?", "What have I learned?" Furthermore, they may also ask for topics and relationships that are still unclear to the learner. In doing this, a personal dialogue is established between student and teacher, which can be especially difficult to establish in larger groups. According to Stead [Stead 2005], this may improve student motivation.

With the help of our approach and architecture, these scenarios can be brought to the participants by using any kind of computational device (e.g. notebook, smartphone, tablet) and the students' favourite input channels. Providing an environment that enables a computer-supported variant of the One-Minute Paper method brings relief to teaching staff by saving time and material compared to the pen and paper version. Students' comments can be easily organized, compared, visualized and stored. Especially for larger amounts of students, this is expected to ease the handling of learners' feedback. First experiences on the use of a web-based input service (available to smartphones, tablets and notebooks) to realize the One-Minute paper method have been recently described by Bollen et al. [Bollen et al. 2012].

5.1.2 Supporting Self-Learning Phases

Another application scenario is the support of self-learning phases between classroom sessions. It is important for students to be able to transfer the newly acquired knowledge to situations in their everyday life. The discovery of one's own examples, together with sensitivity for similarities and applicability, does also ideally lead to a deepening of knowledge and makes learning contents more easily retrievable when needed.

Tasks like this can appear in almost every domain at every stage of a lecture, seminar or student project. Results can be collected and visualized for an in-class usage. Besides this, as mentioned before, students are regularly prompted to report on situations and examples that illustrate the learning content. Therefore, the learner would be able to contribute and share examples for future sessions.

As an example, which originates from first experiences and trials, the learners' task was to relate a new topic in a seminar with everyday life's experiences. The teacher prepared sentence opener questions to guide the learners, who had one week time to collect and communicate their findings - using tablets, notebooks or smartphones and wherever and whenever appropriate.

Again, the proposed architecture allows for a flexible generation and accumulation of students' contribution over time, together with a visualization support that helps teachers and students likewise organize and share results.

5.1.3 Group Discussion Support

As a third application scenario, we present a situation that utilizes the described architecture in a synchronous, co-located manner. In a classroom situation, the proposed system can be used to visualize textual contributions that have been created by the learners and sent from various sources. These contributions are received and processed immediately and can be presented with the help of a large, shared display, e.g. by using a video projection. Similar approaches have been described, e.g., by Liu and Kao [Liu & Kao 2005] and by Bollen et al. [Bollen et al. 2006].

By these means, classroom discussions can be supported in a way that can be beneficial in a number of ways:

- contributions can be formulated and submitted without interference and influence from peers
- contributions can be submitted anonymously, which can raise participation in controversial topics or for more introverted persons
- the course and structure of a discussion can be made explicit in a shared visualization
- discussion results can be stored for later (re-)use, review and comparison

Scenarios like those described above benefit from the integration of Cloud Services by increasing interoperability of peripheral devices. Heterogeneous Cloud Services like Twitter and Facebook allow participation independent of both location and time.

When applying the categories introduced in section 3 - Cloud-based Communication Services, Repository Services, Production and Processing Services, the above mentioned example "Mobile Contributions" falls into the categories Cloud-based Communication Services and Cloud-based Production Services. As it supports the creation and submission of students' contributions via channels like Twitter, Facebook or the web, it obviously acts as a Communication Service. By integrating various existing, web-based communication services to a new, unique service with additional functionality, it demonstrates the opportunities of creating "added value" by integrating cloud-based services.

Apart from that, the MoCo's visualization component to show, filter and sort the students' contributions can be categorized as a Production Service. Here, the teacher creates a new artefact in his educational context, using the students' contributions as building blocks for a larger product.

5.2 Supporting Learning of Signal Propagation Patterns

Secondly, we present another educational scenario which utilizes cloud computing services in a different way. Here, the aim was to use the principles of SOA for developing systems in the sense that we do not want to re-implement functionalities which are publicly available but to develop the “glue” code for combining them and implement the missing functionality which is not available in such a way previously.

The system was developed in order to support students learning how theoretical models about wireless signal propagation can be applied to evaluate the effectiveness and efficiency of a certain arrangement of antennas [Baloian, Frez et al. 2012]. The learning activity encompasses two phases: the first one is the theory session where students learn in a classroom setting the various existing models for simulating the signal propagation. In the second phase, a practical workshop is performed, which starts by defining working groups consisting of four students each. Two of them take the role *planners* and the other two the role of *measurers*. The tasks to be performed are also divided in two stages: the first one is the **input of data** stage and the second one the **evaluation** stage.

During the **input of data** stage *planners* will make a signal coverage analysis for a set of existing real antennas using a signal coverage simulation tool (see Figure 3) and a collaboration tool (see Figure 5). Both tools have two different interfaces implemented, one designed to be used on a desktop PC and the other to be used on mobile devices (see Figure 4). Students get the necessary information to feed the signal coverage analysis tool which actually performs the simulation after students choose the propagation model they consider is the most adequate given the cartographic information provided by Google Earth. Once the simulation is performed and simulated data about the signal strength for the whole area is obtained students receive a set of coordinates of various geographical points, which they have to input into the collaboration tool along with the data about the simulated signal strength for each of these points. During the **evaluation** stage, *planners* and *measurers* work using a collaboration platform in order to find which is the model that better predicts the real measured values.- Since no single model, which predicts the real value for the whole area. The actual learning occurs when students have to justify the reason for this, by checking the different geographic and building scenarios in site.

The software consists of two applications, one for each role. These are the Coverage Analysis tool for planners and the Collaboration tool which is used in both steps by both roles. The **Coverage Analysis tool** has two interfaces, for desktop computers and for mobile devices. The desktop interface supports the planning activity in the classroom which includes performing simulations and storing the generated data. The mobile interface is designed to provide the simulation data while working on the field. The Desktop interface has following main features:

- **Add Transmitter:** To locate a virtual antenna over a 3D map provided by Google earth (see Figure 3). Technical specifications of the transmitter can be filled in a pop-up form.
- **Evaluate the Spatial coverage:** This function performs the actual simulation by computing the signal strength in the whole area

The Mobile interface allows students to retrieve the simulated signal strength values while students are working on the field. The system shows the simulated signal strength emitted from the selected antenna at the device’s position according to all available models. Figure 4 illustrates the system’s interface for the mobile devices.

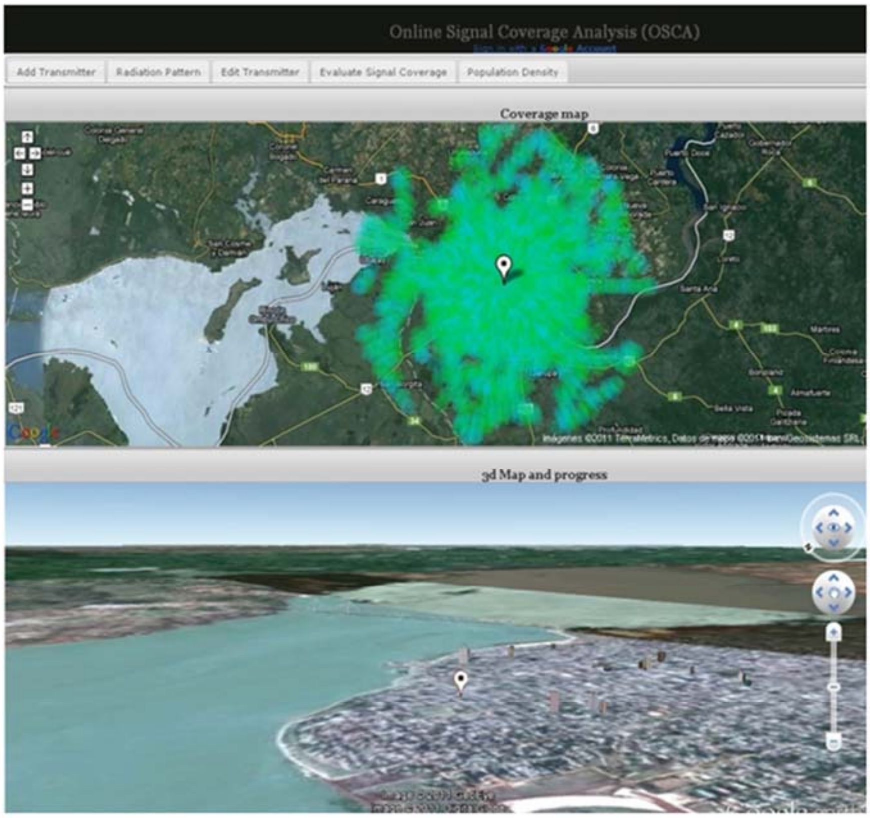

Figure 3: Coverage analysis tool with the 2d (up) and 3d (bottom) views (running in desktop browser)

The **Collaboration tool** has also two interfaces, for desktop which is used during the planning phase, and for mobile devices, which is used on the field while students are measuring the signal strengths. The following are the main features:

- **Report a Simulation (desktop version only):** Students publish the simulated signal strength for a certain location.
- **Vote**: During the evaluation step students have to choose the most adequate model to predict each measured value of the signal's strength. While planners have better information about the simulation results and the geographical characteristics of the area between the antenna and the device position, measurers have on-site information about the local conditions for a certain point. Both actors can use the voting system to express their preference for one model or the other according to their information.
- **Report a Measurement** (mobile version only, cf. Fig. 5): This functionality allows *measurers* on the field to publish measured values they measure. The

system automatically adds the location information using the GPS feature of the mobile device and shows it on a map.

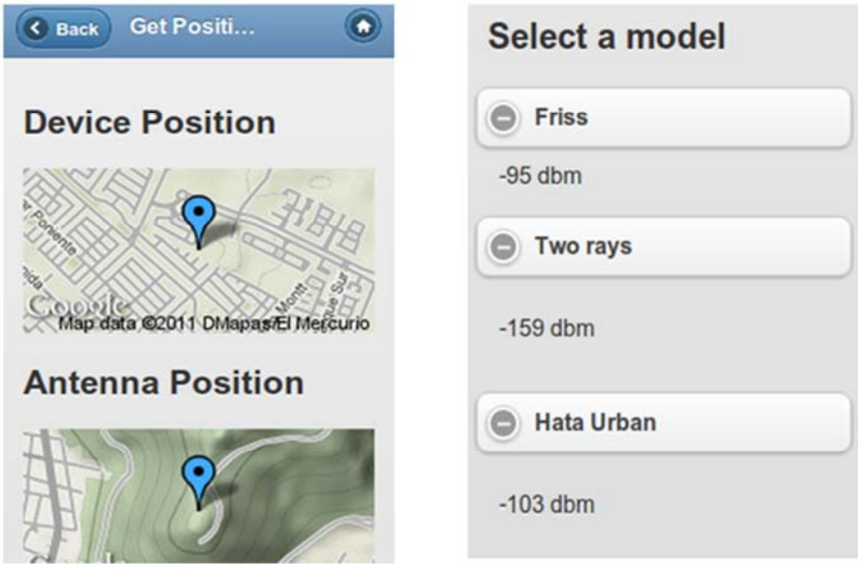

Figure 4: The picture on the left shows the upper half of the mobile device's interface. The map on the top shows the student's current position according to the device's GPS. The map on the bottom shows the antenna's location. On right, the bottom half of the interface shows the signal strength values according to each available model.

In this software Google Earth is used by the Coverage Analysis Tool to let the student situate an antenna on the map. Google Earth instead of Google Maps should be used because the elevations in the terrain are an important parameter for simulating the propagation of the signal. In the field, the Collaboration Tool uses Google Maps in order to locate the place where the real and simulated values will be compared. Here, the elevation is not of that importance and Google Maps is better for being used by mobile devices because it requires less resources. Twitter is used in the collaboration tool for implementing the discussion and voting functionality. The new functionalities implemented by the Coverage Analysis Tool are the simulation process and the visualization of its results, as well as storing the simulation results in a repository. The Collaboration Tool implements the retrieving of this data as new functionalities.

Concerning the classification along the categories from section 3, the Signal Propagation Pattern example naturally fits mainly into Category 1: Cloud-based Communication Services (for the implementation of the discussion among students) and 4 (for the simulation of the signal propagation)

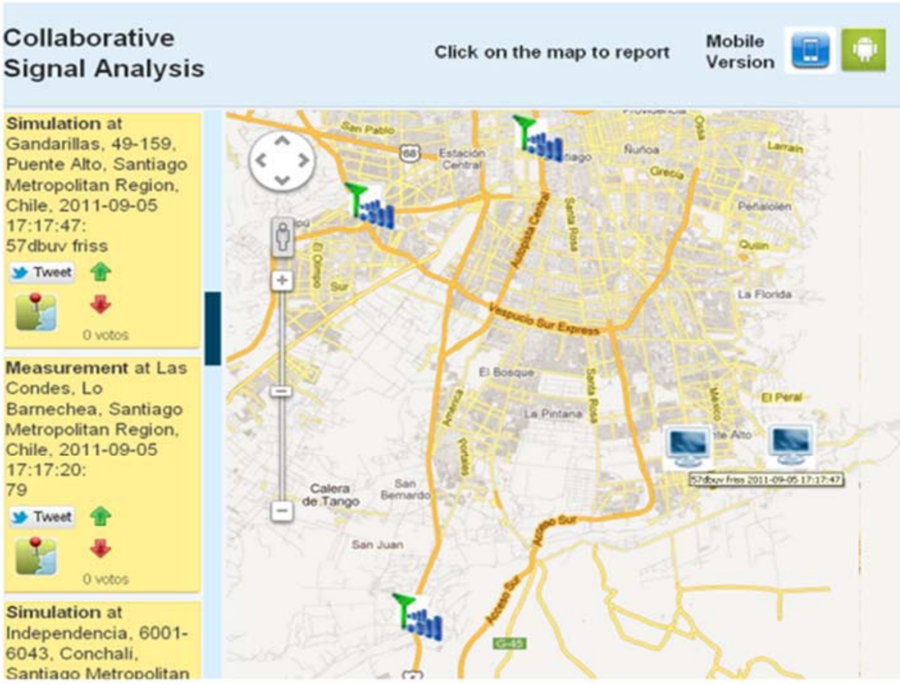

Figure 5: Desktop web browser interface used for entering simulated or measured signal strength values for various locations. (The user clicks on the map and enters the information. On the left column, detailed information is shown.)

6 Interoperability and Scalability of Scenarios

Important features of computer-supported learning environments are interoperability and scalability towards educational scenarios. Is a learning environment (or a set of a interoperating environments) scalable a) against an advancing number of different scenarios and b) against a varying number of involved students? Is a learning environment (or a set of learning environments) providing interoperability between different education scenarios, i.e. does it support smooth transitions between varying scenarios?

Most notably, computer-supported learning scenarios can be categorized along the dimensions of

- time: Is the user interaction in this scenario synchronous or asynchronous?
- location: Are participating learners are co-located or in remote places?
- group scale: How many learners are interacting in the given scenario?

To give two examples, in this scheme, a classroom discussion would be considered a synchronous, co-located scenario in a large group. A collaborative modelling activity between two learners using a shared workspace environment would be a remote, synchronous scenario in a dyad. Figure 6 illustrates the dimensions described above:

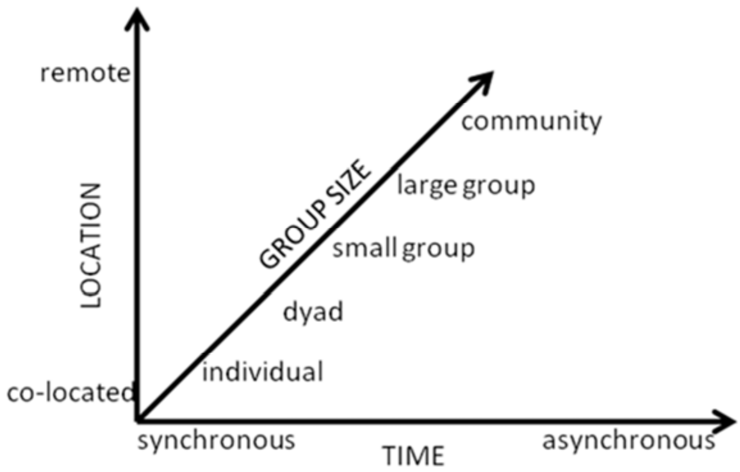

Figure 6: Dimensions of educational scenarios

Along these dimensions, we can further explain the aspects of interoperability and scalability of computer-supported learning environments. We can regard an environment being scalable, if it allows the realization of scenarios along instances of the dimensions mentioned above. We consider an environment being interoperable between scenarios, if it allows smooth transitions between instances of various scenarios.

As an example, if an environment allows the collection of learner's contributions individually over a period of time, and is able to present these contributions using a shared display in a classroom context, this environment is capable to scale over time and group scales, and we may consider it as being interoperable, if the transition between those scenarios requires little or no effort (concerning the use of devices, different software or configurations).

Here, we claim that the use of Cloud services (especially in a way presented in the architectures above), is a means to gain high scalability and interoperability, not only between hardware devices, operating system and software applications, but in particular between educational scenarios. From the point of view of cloud services in educational scenarios, which we are presenting in this article, cloud services are regarded as being advantageous in the context of this section, as they denote a very high accessibility in terms of time, devices, and platforms.

7 Outlook and Future Work

The presented approach and examples for the integration of Cloud Services into educational scenarios will in the future be used for the implementation of more flexible learning scenarios. In this scenarios students can participate independent from time and location and by using their favourite communication channel. Informal learning scenarios can particularly benefit from this kind of participation, as it allows for an easier contextualization of the learner, which is still a hot topic, in mobile learning scenarios for example.

The examples that we have gathered and analyzed make use of Cloud Service for communication and basic information input (such as geographical information). We would not call any web application integrating such basic services a Cloud Service in itself (this would depend on the realization of general criteria such as scalability, virtualization etc., as explained above).

From a pedagogical point of view, Cloud Services can be important building blocks in Personalized Learning Environments (PLEs) that support self-regulated learning [Kroop et al. 2012]. In this paper, we have characterized and exemplified potential functions of Cloud Services for learning purposes, but more research is needed to explore fruitful combinations and “learning flows” based on these elements. Using basic Cloud Services is still characteristic for many instances of educational usage. For the future, we see a specific interest in services for rich production and processing, the latter especially for learning analytics. This could provide a suitable and easily accessible way of value enrichment for many web-based learning platforms or environments.

Furthermore, we hope that our categorization can be used to guide empirical investigations in areas such as ease of use and usefulness of mobile devices in educational contexts, of relations between user traits and technology usage, or in uncovering usage patterns in this innovative field of computer-supported education. Also, the use of such services increases the possibilities for integrating analysis and context-awareness mechanisms, e.g., by using social network analysis or educational data mining techniques.

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