An Architecture for Mobile-based Assessment Systems in Smart Learning Environments

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Abstract. Assessment is a fundamental part of the learning process and therefore a key aspect in smart learning environments. Despite the existence of some architectures and frameworks for supporting assessment with mobile technologies, there is still a need of more research on how these systems should be designed for smart learning environments. In this paper we extend previous research on mobile-based assessment to introduce an architecture to inform the design and development of mobile-based assessment systems for smart learning environments to foster smart learning. The architecture consists of a client side (mobile app) and a server side web application. Preliminary results obtained from an evaluation study shows high levels of students' acceptance and intrinsic motivation after using a mobile-based assessment application that implements the architecture.

Keywords: mobile-based assessment · smart learning environment · Mobile learning · Software architecture.

1 Introduction

Assessment is a fundamental part of the learning process [1] [2] that can be supported by mobile technologies [3]. Mobile technologies are useful for managing assessment processes in terms of distributing exams, collecting responses, providing automated revisions, feedback and consolidating information [4]. In that regard, according to the UNESCO [4], mobile technologies (and in particular mobile-based assessment systems) can improve assessment processes by providing immediate information about students' progress as well as instant feedback. These features are useful for helping students to advance in their learning process and provide teachers with information to identify if students are making progress or not so that teachers can make the necessary changes in teaching. Given the importance of assessment in learning processes, research on mobile-based assessment systems is important for improving learning processes when mobile devices are used in the

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classroom. Consequently, there is a need of efficient processes and methods for improving assessment processes in the context of smart learning environments.

In this paper, we briefly introduce an architecture to inform the design and development of mobile-based assessment systems for smart learning environments. Moreover, we describe preliminary results of an evaluation study of a mobile-based assessment application for English language learning developed according to the architecture. The rest of this paper is organized as follows: section 2 describes the related work and section 3 presents the foundations of the architecture. Next, sections 4 and 5 describe the client side and server side of the architecture respectively. Section 6 describes an example of implementing the architecture in the K-English application and section 7 describes the preliminary results of the evaluation study. Finally, section 8 presents some conclusions and future work.

2 Related Work

Previous research on mobile-based assessment systems have resulted in the definition of some architectures and frameworks to inform the design of such systems. For instance, Abdulwahed, Nagy and Blanchard [5] introduce an architecture for providing automatic formative assessment through feedback using SMS messages. El-Sofany and El-Seoud [6], developed a web-based assessment system with a mobile version based on semantic web. Ontologies are used for providing adaptive learning and contextual knowledge for the learning objects. Huang, Lin and Cheng [7] developed an adaptive testing system based on particle swarm optimization and Item Response Theory for providing formative, summative and self-assessment tests. Another approach was adopted by Riad and El-Ghareeb [8] who introduce a service oriented architecture including software agents and recommendations for mobile assessment learning management systems. On the other hand, the architecture introduced by Nguyen and Pham [9] is based on context-awareness and personalization to prepare students for the TOEFL exam. However, each one of these architectures and approaches focused on important but very specific independent aspects of the assessment process such as feedback, adaptive assessment, self-assessment, delivery, multimedia among others. These aspects are part of smart learning environments but a broader perspective that integrates these aspects with pedagogical components to create “smart learning” [10] is still needed. To address this research gap, in this paper we extend previous research in mobile-based assessment and we introduce an architecture for mobile-based assessment for smart learning environments with a broader perspective for fostering smart learning. In that regard, we contribute to the research on the adoption of personalization and context-aware technologies in mobile-based assessment systems [11].

3 Foundations of the architecture for mobile-based assessment systems for smart learning

The architecture is aimed at guiding researchers, practitioners and other stakeholders in the development of mobile-based assessment systems for smart learning environments. The architecture consists of two main sections: 1) Mobile-based assessment (client side) and 2) the Web application (server side).

Fig 1. Architecture for mobile-based assessment systems in smart learning environments.

Figure 1 shows the architecture. Our architecture is based on the Triple-A model introduced by Wang et. al. [12] and includes some aspects of smart learning environments. The Triple-A model consists of the following components:

- Assembling: Component dedicated to managing (designing and implementing) the items for the tests and scheduling the tests. In our architecture this component is equivalent to the web application that is on the server side (see section 5).
- Administering: Component that is in charge of applying the tests to students and gather information from this process such as answers and scores. In our architecture this component is equivalent to the mobile application (client side of our architecture – see section 4).
- Appraising: Component that process the data collected from the mobile-application to show results and information to teachers. In our architecture

this component is also on the server side (see section 5) to generate the learning analytics and reports that can be useful for teachers.

Section 4 describes the Mobile-based assessment component (client side) and Section 5 describes the Web application (server side).

4 Mobile-based assessment (client side)

This section of the architecture represents the mobile-based assessment component that is used by the students during the assessment process. This section of the architecture implements the administering component of the Triple-A architecture and is divided into the following modules: interface and Support Services (see section 4.1), Pedagogical Components (see section 4.2), Assessment (see section 4.3), Learning Analytics (see section 4.4), Recommender Module (see section 4.5), Data Access Services (see section 4.6).

4.1 Interface and Support Services

This component of the architecture consists of the following three components: The user interface manager, Authentication and Notifications receiver.

- **User Interface Manager:** this component manages the user interface and interaction with the users. It includes the mechanisms for providing support for different resolutions and screen sizes for the different mobile phones.
- **Authentication:** Since the mobile application can be installed by many students, it is important to identify which instance of the application is being used by each student so as to have a personalized report for each student. To do that, each student receives a unique numeric code (Personal Identification Number - PIN) that is generated by the teacher using the web application. This code can only be used once and is used to unlock the mobile application in the students' smartphone so that the instance of the application can be associated to only one student. This unique code identifies students in the system and is used to store all the information about the students' progress and to provide personalized services. Students only need to insert the code once they install the application.
- **Notifications Receiver:** this component works as a service in the mobile application and is designed to receive push notifications that are sent by the web application. The purpose of these notifications is to provide timely feedback and recommendations to students on how well they are doing in the application or what they need to improve or practice more. This component

was defined according to the findings of some authors with respect to the positive effect of feedback on students' learning outcomes [13] [14].

4.2 Pedagogical Support

This module consists of the following components: scaffolding and feedback. These two components are described as follows:

- **Scaffolding:** Scaffolding is defined by Shepard [15] as the "support that teachers provide to the learner during problem-solving – in the form of reminders, hints, and encouragement – to ensure successful completion of a task". Scaffolding, has a positive effect on students' learning outcomes in e-learning applications [16]. In our architecture, the scaffolding component provides hints and clues to help students to solve the items of a test in the context of a formative assessment. The provision of scaffolding is quite relevant for helping students to achieve mastery in the topic. In the context of smart learning environments, the scaffolding component takes advantage of the recommender module (see section 4.5) to provide a personalized scaffolding according to the students' level of competence in the topic or according to the students learning style. Some examples of scaffolding mechanisms for a mobile-based assessment application can be: to include a mechanism that removes one or two incorrect options from a multiple-choice question (50/50) or to provide hints or clues to students in order to help them to answer an item. These mechanisms are intended to help students to gain expertise in the learning topic. When students reach certain level of mastery the scaffolding mechanisms could be automatically removed.

- **Feedback:** Feedback is defined "as information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding" [13]. Feedback is considered to be one of the most important factors that positively influence students' learning outcomes [13] [14]. Based on the importance of feedback in the literature, the feedback component was included in the architecture proposed. The main purpose of the feedback component is to provide positive and attributional feedback so that students achieve mastery in the topic. This component works together with the recommender module in order to provide personalized feedback so that the feedback can be adjusted to the students' level of competence or students' preferences and needs. Feedback can be provided for each answer to an item. This might include providing feedback when the answer to an item is wrong and explaining why that answer was wrong or positive reinforcement when the answer to the item is correct. Machine learning techniques can be used to provide some form of automatic and personalized feedback.

4.3 Assessment

This module of the architecture contains all the functionalities to deploy the tests and items that students need to solve in the mobile-based assessment application.

- **Questions Manager Engine:** this component encapsulates all the mechanisms for displaying different types of questions (items) to students. This component needs to be able to display different types of items such as multiple-choice questions, true/false, open-ended questions, fill in the blanks, etc., depending on the learning topic and the teacher needs. This component needs to be developed with mechanisms to check the correct answer to an item and to associate the appropriate scaffolding and feedback mechanisms to each item. We suggest that the mobile-based assessment application can be developed with a mechanism that retrieves the items from a server to reduce the resources consumption. The question manager engine can take advantage of personalization and adaptive mechanisms to display the items according to the students' levels of competence, preferences, needs, interests or contexts.

4.4 Learning Analytics

This module of the architecture consists of components that gather information about the students' use of the application with the aim of showing information about their progress in the assessment process. Moreover, this component sends information about the student use of the application to a server in order to show visualizations that teachers can use to make decisions on the assessment process (see section 5). The learning analytics module consists of two components: the learning analytics (students' view and the Monitoring Module that are described as follows:

- **Learning Analytics (Students' View):** this component of the architecture shows some visualizations and statistics to students so that they can be aware of the progress they are doing with the mobile-assessment application. The definition of this component is in line with the recommendations of the Universal Design for Learning framework [17] to reduce barriers in the learning process. These visualizations might show how is the student's progress in relation to the rest of their peers. The visualizations could be processed by the server (web application – See section 5) and sent to the mobile device.
- **Monitoring Module:** this component monitors students' activity using the mobile-based assessment application. Some of the actions that can be gathered by the monitoring module are: the use of the scaffolding mechanisms, the amount of time that each student spent answering an item in

the system, the answers provided by students, the context in which students are using the application among other aspects that can provide information to the system in order to feed the visualizations for the learning analytics module or to provide information to the recommender module to personalize different aspects in the application (See section 4.5).

4.5 Recommender Module

The recommender module provides all the services of personalization and adaptive processes as one of the core aspects of a smart learning environment [10]. In that regard, the architecture for a mobile-based assessment application should include a recommender module that provides all the services needed to personalize the interface, content, scaffolding or other services according to the students' needs, preferences or interests. This module includes one suggested component:

- **Local Recommender:** this component is in charge of providing all the mechanisms of personalization and adaptation based on the information provided by the other components of the architecture, in particular, the local recommender works with information gathered by the Monitoring Module (see section 4.4). Semantic web technologies can be used to create a model of the learning domain and a model of the interaction of students to provide recommendations. Moreover, some models based on the Item Response Theory can be used to provide recommendations on the items that students need to practice more according to their performance. In addition, classification methods and convolutional neural networks (CNN) can be used to provide the recommendations. If these processes demand too much computing resources (memory, processing, etc.), the recommendations can be generated by the server side of the architecture (see section 5) and can be deployed by the local recommender component. Some examples on how the recommender module provides services for other components of the architecture are:
    - It might personalize the scaffolding, feedback mechanisms and the difficulty of items according to the students' needs or according to the students' level of competence in the topic.
    - It might adapt the recommendations to students according to their progress in the assessment process.

4.6 Data Access Services

This module of the architecture provides services for the local storage of information that the application needs to work correctly. In this module there is one

component: Mobile Local Data Storage Service**.** This component provides a service for storing data in the mobile device. For instance, the application could store information about the student who is using the application or how frequently students use the application in the mobile device and synchronize this information to the server on a regular basis. This mechanism allows the application to send information to the server from time to time to avoid bandwidth saturation.

5 Web Application (server side)

The server side of the architecture consists of a web application that is located in a server. This part of our architecture extends the Assembling and Appraising components of the Triple-A model [12]. The web application provides different functionalities such as: creating the question (items) bank, creating the PIN code for students so that they can use the application, processing the data sent by the mobile application to show visualizations (learning analytics) to teachers and run the algorithms for providing the services of personalization.

6 Implementing the architecture (K-English application)

K-English is a mobile-based assessment application that implements the architecture introduced in this paper. The main purpose of K-English is that students can practice six of the types of questions (items) from the Cambridge KET (Key English Test) exam. These six types of items allow students to practice reading comprehension, listening and grammar (use of English). Figure 2a shows the main menu of the application where students can choose one of the six types of items for practicing.

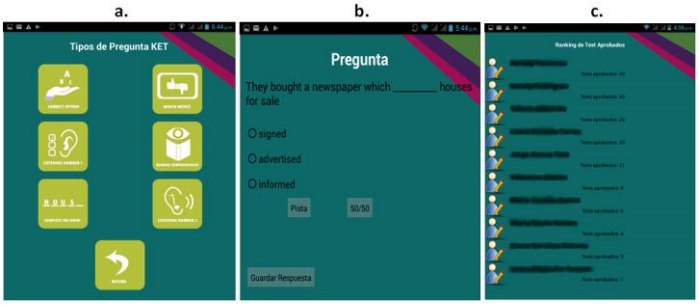

Fig 2. Screenshots of the K-English mobile-based assessment application.

Figure 2b shows one of those types of items and the two scaffolding mechanisms developed for K-English: the clue and the 50/50 option. Currently the application has 305 items for all six types of items. Figure 2c shows a ranking in which

students can see how they are doing with respect to their peers. The students' names have been removed to protect their identity. On the server side, a web application was developed. This application can be used to create the items bank, manage users and collect information about the student use of the application.

7 Preliminary Evaluation Study

The K-English application was tested with 100 university English language students (30% male and 70% female) from A1 and A2 levels from the Common European Framework of Reference for Languages (CEFRL). The age range of the participants was between 15 to 26 years old. Students used the application for a period of four weeks and answered an adapted version of the Mobile-based Assessment Acceptance Model [18]. Overall, we found promising results that show high levels of students' acceptance of the system. The mean values (in a scale from 1 to 5 where 5 is the maximum value) and standard deviation for each one of the evaluated dimensions of acceptance were: Feedback (M=3.6; SD=0.74), Behavioral Intention to Use (M=3.8; SD=0.77), User Interface (M=3.8; SD=0.72), Perceived Usefulness (M=3.9; SD=0.59) and Perceived ease of use (M=4.2; SD=0.74). We also evaluated two dimensions of student intrinsic motivation such as pressure/tension (M=2.8; SD=0.76) and importance (M=3.8; SD=0.54). As for the data collected by the monitoring module, the web application collected more than 12000 answers to the items. The scaffolding mechanisms (hint and the 50/50) were used 2625 and 2038 times respectively and the total amount of time that students spent answering all of the items was 84 hours. In general, these results suggest that students were engaged with the use of the application and it shows that students are using the scaffolding mechanism as a support for practicing in the application.

8 Conclusions

In this paper we introduced an architecture for the design and development of mobile-based assessment systems for smart learning environments. From a preliminary study conducted with the application, it shows that students engaged with the use of the application and the acceptance was high. We also concluded that the application allowed us to collect a large amount of data about the use of the application. This data is a valuable source of information that can be used to train algorithms for providing a personalized learning experience in mobile-based assessment systems. For future work, we are planning to compare students' learning performance with a control group of the same English levels to determine if is there any significant difference between the use of the application for practicing and the use of traditional learning materials.

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