CS Training: Introducing Mobile Educational Games in the Learning Flow

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Abstract-**This paper describes a general model for the integration of portable game devices (e.g. Nintendo DS™) in preexisting e-Learning systems, also known as Learning Management Systems (e.g. Moodle™). This integration simplifies the deployment of educational games in the classroom and provides instructors with information about what students are actually doing with the games. The general model is exemplified with the development of CS-Training, an educational application for undergraduate Computer Engineering education.**

I. Introduction

Digital game-based learning and game-like simulations are becoming an increasingly recognized trend in Technology-Enhanced Learning (TEL). In particular, they have caught the attention of instructors in science and engineering fields, who are starting to consider video games and game-like simulations as an alternative to traditional methods [1-3]. Among the potential benefits of video games, researchers have identified their ability to engage and motivate [4, 5], the solid educational principles that can be built into the games [6, 7], the alignment that exists between games and Problem-Based Learning (PBL) [8], or even their potential to attract students belonging to different demographic populations towards science and engineering careers [1].

In addition, there is another trend of TEL that advocates for the use of mobile devices, arguing that they can enhance the learning processes in different ways: the so called mobile learning or just *m-Learning*. Taking the broad acceptance of mobile devices as a basis, its potential in education has been demonstrated through multiple pilots and applications, opening new horizons in terms of ubiquitous learning, augmented reality, and many other applications [9, 10]. However, how to effectively integrate these devices in the learning process, given the complexity that they introduce, is still an open issue in the agenda of TEL.

Nowadays mobility is also a driving force in gaming, with portable game consoles outselling regular home consoles (e.g. the Nintendo DS™ console has sold more units worldwide than the three last-generation consoles together[1]). Besides, as PDAs and cell phones are increasingly becoming more and more sophisticated, they are also becoming relevant mobile gaming platforms [11]. The rise of the mobile gaming industry has also been recognized by of scholars and researchers from the educational gaming field, who are starting to consider them as valuable tools for learning [12-14].

However, games are not necessarily valuable educational resources on their own. For example, in learning complex domains, where the students need to acquire a lot of knowledge and diverse skills, it is unlikely that games could completely replace other activities. Additionally, the effectiveness of educational games is higher if they are focused on concrete aspects and have clearly defined reasonable learning goals. This suggests that games should be part of broader educational modules, focusing on specific topics, complementary pieces of content or evaluation tests, or targeting the acquisition of specific skills.

Nonetheless, combining educational games and other kind of activities within a solid instructional approach introduces diverse difficulties, especially when it comes to the use of mobile devices. Ideally, in order to provide an effective use of the games, the learning process should be managed by an instructor. Unfortunately, adding games to a pre-existing educational process in a manner that can be tracked and managed by an instructor is not always an easy task. In a classroom environment, it is difficult for the instructor to make sure that all the students are playing the game correctly (or even doing it at all) and learning the right lessons, as it is difficult to track the in-game performance of the students while they play at their own pace.

Portable game devices can help in addressing this issue, as they offer a broad range of connectivity options. This connectivity can be leveraged to communicate information about the game experience to a central repository of information. In turn, the instructor can track the gathered results and use them for assessment purposes. In addition we can take advantage of current e-Learning systems, which are broadly accepted within the academic community as support tools of the learning process (e.g. Moodle™), to facilitate the tracking and assessment of the learning process with mobile devices.

In this paper we discuss the challenges involved in the integration of portable game devices in e-Learning environments as well as the benefits this would imply, and propose a specific middleware to link educational games being executed in portable game devices with the most common e-Learning systems. This middleware laid the base for the development of CS-Training, a suite of portable educational games in the field of Computer Engineering.

[1] Source: http://www.vgchartz.com

Thus the paper is structured as follows: first, in section II we discuss the potential of mobile game-based learning and issues that are preventing its adoption. Then, in section III we describe the middleware that we propose. In section IV we describe CS Training as a specific instance of the middleware that exemplifies our approach in the domain of Computer Science Engineering. Finally, in section V some conclusions are future lines of work are discussed.

II. Integrating Games in the Learning Flow

Even if the potential of video games and mobile devices for learning is becoming more and more accepted, there are still some issues that need to be tackled. In this section we briefly discuss the potential of video games and portable devices for education and how to effectively involve instructors, which is one of the most relevant open issues.

A. Game-based learning with mobile devices

The discussion about whether games should be used in educational settings is rapidly converging to a common acceptance of their potential, even if the exact elements that make an educational game successful remain an elusive concept [15]. In order to design good educational games, it is necessary to understand which elements turn an interactive piece of content into a game. What seems to be clear in game design is that players are attracted by competitive challenges, especially if they are backed by a perception of progress [16].

When educational games fail to connect with the instincts of competitiveness and self-improvement, the result is usually a boring product that is not perceived as a game. The essential ingredients that a game needs are an objective, a set of rules and a very short feedback cycle that allows players to perceive their progress towards the final objective.

Along these features is Dr. Kawashima's Brain Training™[2], an educational game for the Nintendo DS™ console focused on exercising our mind's agility, as a game version of his book *"Train your brain: 60 days to a better brain"* that achieved a great success in Japan [17]. As opposite to other commercial videogames, the strategy followed in Brain Training™ to engage players relies on the fostering of competition, instead of investing in complex and expensive technology. The simple *"How Old Is Your Brain?"* metaphor, set as a game objective, is a great example of how including game elements into our educational content can turn a set of mathematical exercises into a best-selling game. The game uses the player's performance at solving a heterogeneous set of exercises, along with the time needed to solve them, to produce a single comparable number that is recorded for comparison between executions: the *mental age* (Fig 1). Given that the *mental age* is a comparable measurement (can be compared either with previous executions or with results achieved by other people), it turns the exercises into a game as it fosters 'good' competition. The game also manages to keep the attention and interest of the player by offering a diversity of exercises designed to be brief, making each execution different.

[2] The game was released in PAL regions as Brain Training™ and in the United States as *Train Your Brain*™ .

Games like Brain Training™ take advantage of the special freedom and interactivity that mobile game devices offer. Featuring touchable screens or motion sensors, mobile game platforms are becoming a driving force in commercial gaming. Game players are increasingly adopting portable game consoles such as Nintendo DS™ or PlayStation Portable™, as well as other portable devices like cell phones and media players that are now incorporating games as an added value.

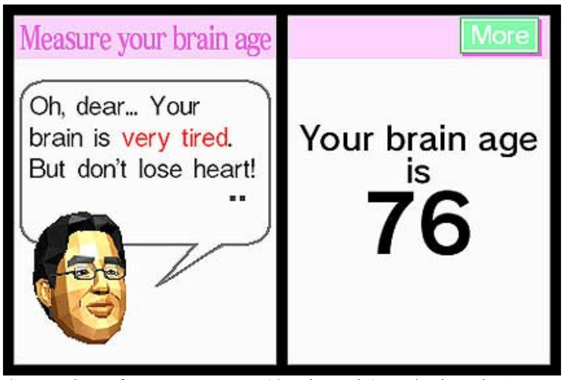

Fig 1. Screenshot of *Brain Training* (© Nintendo). It depicts the 'mental age' metaphor.

The mobility of these devices allows for a more efficient distribution of the games to the students when compared to setting up computer rooms at schools or giving each student a computer. Mobile gaming devices can be played unobtrusively in the classroom or taken out of the school for playing (either as homework or as part of a distance education program).

In addition, most of these devices also include diverse connectivity options (at least, a standard Wi-Fi connection), which can be used to access learning content or to communicate with a centralized server or with other learners to promote collaboration between students in the classroom (Fig 2).

B. Involving the instructor through e-Learning systems

Educational games are sometimes seen as special types of content that engage the students without requiring the involvement of the instructor (only tutorials or instruction booklets). This may have contributed to the broadly accepted misconception that teachers should not be involved in game-based learning. On the contrary, the instructor is a fundamental part of any game-based learning process, providing guidance, help and support for the students. In addition, instructors should be able to track which students have played the educational games, how they interacted with the game and some measures of performance. However, from the instructors' perspective this is burdensome. How can teachers know what use are the students giving to the mobile devices? Are they really playing the game? Moreover, if they are playing, are they trying to trick the system? In short, are they really learning?

This issue could be tackled by taking advantage of the existing e-Learning infrastructure. Nowadays, most educational institutions (especially in higher education) are adopting Learning Management Systems (LMS) such as Moodle™, Sakai™ or WebCT/Blackboard™ as a complement to traditional education [18] due to the wide support they provide for all the roles involved in the learning process (i.e. students, instructors, content creators, etc.).

Fig 2. The Wi-Fi connection allows portable game devices to communicate with a LMS to exchange information for tracking and assessment.

LMS allow exploiting the technology in the form of courses, featuring live chats, grade ranks and virtual lessons. Even in traditional lecture-based educational programs, these systems make it feasible to store the results that students obtain so the instructor can track and access the progression of each student. Moreover, this information can be available for the students as well, if the instructor find it useful, as a source of feedback. Additionally these systems offer a unique collection of teaching tools that allow instructors to have a more effective involvement in the game-based learning experiences, which avoids the perception of lack of control over the learning process that video games provoke in many instructors [19].

If we leverage the connectivity of mobile devices to store information in a LMS, the instructors will be able to track the performance of each individual student using the same tools that they use for other evaluation and tracking activities.

III. A General Model to Integrate Portable Game Devices into the Classroom

In this section we discuss a general model to bring portable game devices to educational settings, allowing the instructor to control the student's progress, offering the students new opportunities and incentives to learn.

This general model considers a portable game device and a LMS, both linked through the device's wireless connection. The educational application that runs on the mobile device is composed by a set of interactive exercises, each one supported by a specific evaluator, and a global evaluator. When the student loads the game, the device downloads from the LMS an instructor-defined execution profile using a specific communication protocol. When the execution of the game finishes, the grades are sent back to the LMS. The LMS is responsible of managing each student profile with its grades, and allows the teacher to monitor all the process. The next sub-sections describe this model in more detail.

Fig 3. The loader of exercises defines the internal structure of the application executed on the portable game device.

A. *Interactive Exercises as Reusable Units of Learning Content*

Inspired by the ideas in Brain Training™, the basic units of learning content in this model are small interactive exercises focusing on different aspects of the educational topic being covered. These interactive exercises should be based on the problems that are covered in the classroom, with added interactivity and perception of progress to turn them into valid educational games.

In order to provide homogeneous grades with heterogeneous exercises, each individual exercise has its own internal evaluation logic that produces a grade for that individual exercise (i.e. a local evaluator). Each local evaluator has full knowledge of the exercise's topic and possible solutions, in addition to other characteristics (e.g. completion time). All this specific information is considered in order to provide a unified grade to the teacher.

The general game loader (Fig 3) will be responsible for gathering the results the local evaluators produce, generating the final grade taking also into account the time invested to complete the exercises. This produces a normalized single grade, alike the brain age metaphor, which can be compared across executions or between peers, as a mechanism to foster competition.

B. Customization and assessment through the LMS

Instructors interact with the system mainly through the LMS (Fig 4). They can be actively involved in the learning process, devising and generating sets of exercises, tracking and reviewing the incoming grades and intervening whenever it is necessary (for example, changing the set of exercises or providing additional support for students showing low performance).

The basic units of interaction are the customizable tests, which define a set of interactive exercises to be resolved. The instructor uses the LMS interface to select the number and type of exercises, the difficulty level and any additional configuration.

When a student completes a test, the normalized grade is sent to the LMS, where a complete execution history is kept for each student. The instructor can thus track the progress of the students and establish a ranking with the highest scores for each student who has completed the test. This ranking will remain visible to all users of the LMS, promoting rivalry and competition for higher scores.

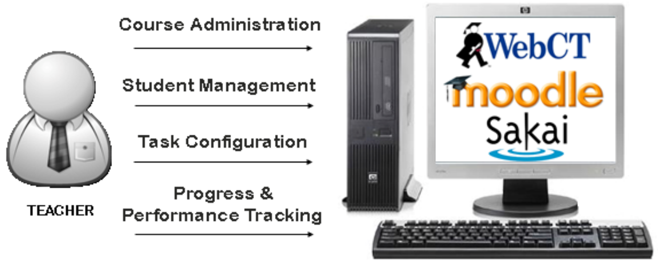

Fig 4. All the most frequent tasks that instructors usually need to perform are supported through the LMS.

In order to create and configure the interactive exercises, the LMS also includes tools that allow instructors to customize their own exercise instances and upload them to the server without requiring any programming or technical knowledge. Instructors without a programming background are able to control and customize the exercise by just specifying the relevant parameters and selecting the graphical elements that are involved in the edition process of the exercise. These tools provide support for managing both the configuration of the exercise and its evaluation logic, so the grading mechanism can be easily customized too.

Using these features as a starting point, teachers may expand the educational content in their courses by adding new kinds of interactive exercises and evaluation logics.

C. Communication through the LMS

The technological complexity that this model implies sets the motivation for enabling the communication and integration among the services of a LMS and the portable gaming device. As we previously mentioned, the LMS is responsible for managing the courses, students, and lessons which compose the closest side to the traditional teaching model of the application. The LMS is also where the instructor configures the exercises and tracks the performance of the students.

The communication is always initiated by the client, but data are exchanged in both directions as follows (Fig 5).

Game device - LMS: The process starts with a client authentication. The students enter their login information into the game and the device uses this information to access the LMS. If this identification is valid and the student is enrolled in courses supported by the service, the device displays a list of compatible courses (i.e. courses with game-based exercises enabled). Within a course, the teacher might have created any kind of exercises or tests. If the student selects one of these tests, the device requests the configuration of the exercises. Once the execution is completed, the device sends the results back to the LMS for subsequent revision from the instructor.

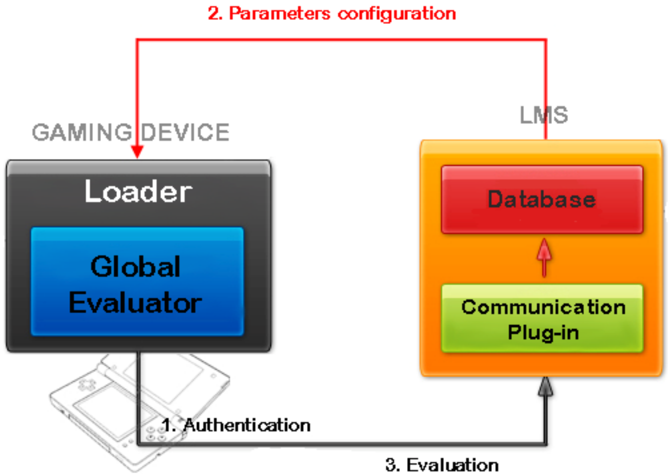

Fig 5. The two-way communication link is established in three different phases, including authentication, configuration and evaluation.

LMS - Game Device: The LMS is constantly waiting for the students to connect, to manage the events of the courses in which they are enrolled, for what it must validate the session coming from the game device. Once access is granted, the LMS provides all the courses that are compatible with the service, that is, the ones that include exercises created by the instructor. When a specific course is selected, the LMS sends back to the device all the configuration and customization parameters for the selected test. When the resulting grade is received, it is stored in the system's database, so that the teacher can check the student's progress. In addition to the grade, the LMS also receives a report of the execution with additional information.

IV. CS-Training

We have used this model to create Computer Science Training (henceforth, *CS-Training*), an online educational complement to be framed in the Computer Engineering degree offered at the Complutense University. The service supports communication between the Nintendo DS™ portable game console and the Moodle™ LMS, following the guidelines of the general model described before.

We have chosen the Nintendo DS console due to its huge worldwide acceptance. Regarding the LMS, Moodle was our preferred choice due to its open source nature, modular structure and compatibility, allowing an easier development of the server-side through its plug-in architecture.

Fig 6. The key in the CS-Training's general model is the communication between the Nintendo DS and the Moodle LMS.

CS-Training provides two modes of use: The first mode is called the Training Mode, in which the students, without any kind of pressure, can freely rehearse and practice the exercises to increase their skills. The second one, the Evaluation Mode, represents the main mode of CS Training. In this mode, a set of exercises will be retrieved from the LMS and the result will be sent back to the instructor. Both modes have access to the same interactive exercises in order to allow the students to practice before being tested.

A. Interactive Exercises for Computer Engineering

Each interactive exercise included in CS-Training is based on a specific subject in Computer Engineering, either software or hardware. According to the kind of interaction they have, there are two types of exercises: "drag and drop" and "point and click". In the fist one, the interaction is done by placing pieces in their correct location like in a puzzle. The second one is based on clicking on the screen anywhere you think is the correct answer, depending on what is displayed. These are some of the interactive exercises we have developed for CS-Training:

Logic Pieces: This "drag and drop" based exercise consists of placing the logic gates in the right location so that the circuit input and output is correct (Fig 7).

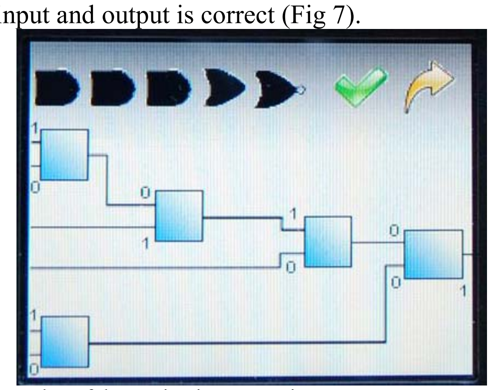

Fig 7. Screenshot of the Logic Pieces exercise.

Circuit Tour: This "point and click" based exercise consists of clicking on the nodes to switch between the binary coded information stored in them, in order to obtain the correct output values that the circuit produces, starting from some given input values (Fig 8).

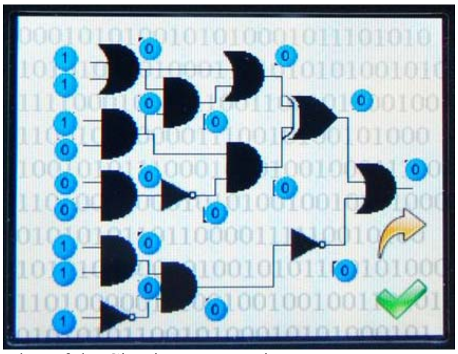

Fig 8. Screenshot of the Circuit Tour exercise.

Electric Currents: Given voltage and resistance data, the objective of this exercise is to mark the direction of the electrical currents through the circuit (Fig 9).

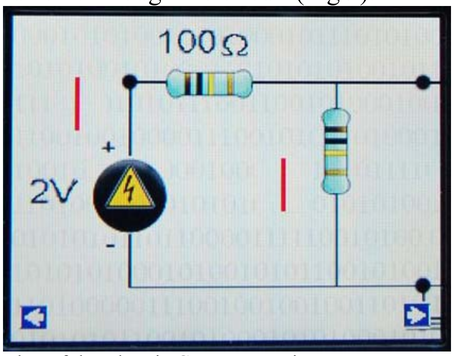

Fig 9. Screenshot of the Electric Current exercise.

B. The CS-Training training module

The Moodle™ LMS in CS Training hosts the various courses that the instructor had enabled, some of them being compatible with the application of the Nintendo DS and others not. In the second case, the instructor may include any material related to the subject according to the students that are enrolled in it.

The courses are determined to be compatible with CS-Training if a) they contain any tests created from the Moodle™ Quiz module; and b) they are enabled for use with CS-Training through a special Moodle™ plug-in that has been specifically produced for this module. The instructors can create and configure those tests by indicating which exercises are included and the number of them.

For each test performed by the student, the LMS keeps a list of attempts, arranged in the form of history, highlighting the highest score obtained so far. Every attempt will additionally contain a report with additional information such as the interactive exercises performed, the grade obtained in each exercise (without normalization), and the time required for their resolution.

By having a detailed report, the instructor can closely observe (compared to the history of attempts made) the progress and advances of the students through the concepts that have been practiced. Low grades in specific exercises, high completion times, etc. may give clues about the performance of the student.

V. Conclusions

In this article, we have proposed a general model to facilitate the integration of portable game devices into the classroom. In addition, we have exemplified the model with a specific application in Engineering Education: CS-Training. This inclusion can be beneficial in bringing the benefits of game-based learning into the classroom with less distribution and logistics issues than their computer-based counterparts.

Handheld game devices can be used unobtrusively in the classroom, or at home as a complement to the activities in the classroom. And, when done carefully, this mobility does not need to mean that the instructor will not be able to track how the students are playing. On the contrary, the communication capabilities of these devices allow the instructors to track the activity of the students independently of where and when they play.

Furthermore, these devices are especially attractive for the students (in some settings, many students will already own some kind of handheld game device) resulting in an overall enhancement of the attractiveness of learning. This is especially relevant in science and engineering education, which is becoming less and less attractive to the next generations [1].

While we have exemplified our architecture with an instance based on the Nintendo DS™ and Moodle™, this solution is easily scalable to other kind of portable terminals (mobile phones, PDAs) with greater communication and computing capabilities. Similarly, this approach could also be applied targeting other LMS platforms, such as Web-CT or Sakai.

This model facilitates the employment of handheld devices, trying to assure that the games improve the participation of both instructors and students, facilitate the monitoring of student and offer a semi-automatic way of creating interactive exercises, tests and other events, while helping students to improve the assimilation of concepts and skills.

Our next plans are to put the CS-Training module into practice in a real learning scenario, which has not been done yet. So far we have just tested our approach with a small number of selected teachers and students in order to get early feedback and test the interest of end-users in this approach. Nevertheless, to measure the real educational value of CS-Training we will need to use it as a complement to the current programme in Computer Science Education at our institution.

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