Educational Games in Higher Education: a case study in teaching recursive algorithms

Eleni Rossiou and Spyros Papadakis, University of Macedonia and The Hellenic Open University

Abstract

In this paper we investigate the worthiness of on-line educational games during synchronous virtual classrooms in Higher Education. An educational game was embedded in one of a series of synchronous Tutoring Tele-Meetings (TTMs) for complementing face-to-face classroom instruction in conventional higher education with methods and tools of Open and Distance Education. Virtual classrooms and educational games provided synchronous tele-educational service complementary to f2f lecturing during the course "Algorithms with C" which is a compulsory (first semester) course of Department of Applied Informatics at the University of Macedonia, Greece. Virtual Classrooms were implemented on CENTRA Symposium platform, through the server of the Hellenic Open University. Educational games were created on the Online Educational Games Central (EGC) of TELUQ University of Quebec, Canada. Thirty three (33) undergraduates of first semester "played" the web-based educational game "Recursive Algorithms", were created based on "Snakes and Ladders" shell. We investigated the easy use of the EGC platform, the students' motivation and their perceptions and attitudes after their experience in blended learning using educational game. Finally, we became conscious of the changes in tutor's role as advisory instructor in a virtual classroom. Regarding the motivational aspects, the first results have been encouraging. Students' effort to win increased their interest for the course and helped them realise misunderstandings and misconceptions on algorithms concepts. Powerful clues revealed that incorporation of games in educational process triggers students learning competitively and enhances their learning cooperatively in a pleasant learning environment. Furthermore, both from students' and teachers' points of view, positive perceptions regarding the effective use of computer games with educational features in education have been raised.

Keywords: educational games, virtual classroom, recursive algorithms, e-learning in higher education

Introduction

Previous students had gained knowledge in a linear mode, mostly from textbooks and through lectures. Our students were taught "Informatics" in secondary education not only in the traditional class but in a lab, as well. They belong to the first generation that has been growing up with new technologies such as www, e-mail, cell phones, digital cameras and (some of them) PDAs and laptops. Because of the fact that they are "wired" in various ways, they have different learning needs but the current traditional classroom setting does not often speak the new digital language used by students today. Educational games encompass a wide range of activities that can support playing, entertainment and learning, teaching of many disciplines. A number of studies (Black, 2001; Liberaman, 2001; Sauvé et al., 2005) have demonstrated the effectiveness of games in education. According to them, games motivate learning, offer immediate feedback, consolidate knowledge, support skills, development and application, aid learning transfer and influence changes in behavior and attitudes. Garris et al. (2002) cite the evidence of learning by playing educational games in three broad categories: skill-based (including technical and motor skills), cognitive learning (encompassing declarative knowledge, procedural knowledge, and strategic knowledge) and affective knowledge (attitudes).

Educational virtual reality games can be very motivating while retaining or even improving the educational effects on students. Vivrou et al. (2005), in order to find out whether the game environment is in fact motivating and educationally beneficial to students and not distractive, conducted an experiment where the game Intelligent Tutoring System (ITS) that operates as a virtual reality educational game, could be compared to an ITS that had a conventional user interface without any virtual reality game. The results from the evaluation showed that students would benefit from educational games in classrooms and would be quite happy to work with a computer game, which represents a more amused teaching fashion than that of conventional educational software. Students who used to be poor performers had benefited the most from the game environment whereas the subgroup of good students had benefited the least from the game environment (Virvou, Katsionis, and Manos, 2005).

Algorithm is a well-defined procedure to solve a problem. The study of algorithms is a fundamental area of Computer Science. An algorithm generally takes some input, carries out a number of effective steps in a finite amount of time and produces some output. A common method of its simplification is to divide a problem into sub-problems of the same type. A method of specifying a process by means of itself is called *recursion*. The *Recursive algorithm* works with smaller and smaller subsets of the original input, doing a little bit of work each time, until it reaches the base case.

In our experiment, we investigated the worthiness of on-line educational games during teaching recursive algorithms in synchronous virtual classrooms. The use of a game as instructional technique aimed to promote students' active participation during educational processes, increase their studying and motivate them to develop their knowledge in recursive algorithms whilst they perform highly enjoyable interactions in order to achieve the proposed goals and self-estimation. We aimed to make complex theoretical knowledge more approachable and support students' learning via educational games. Our research investigates four questions:

1) How easy is the implementation of a web-based game as instructional technique in higher education?
2) What is the effectiveness of the game in students' learning and motivation during the semester?
3) What are the students' perceptions and attitudes after their experience in blended learning using educational game?
4) Which are the changes in teacher's role in teaching by playing?

This paper is organised as follows: first, there is an overview of educational game and the background of this effort is provided. Also, short descriptions of synchronous virtual classroom and e-tools that can be used in order to implement educational game during a synchronous Tutoring Tele-Meeting (TTM) are given. Second, we describe the findings of our empirical study of using educational game for students' self-evaluation in recursive algorithms in the context of the first semester course Algorithms with C, in the Department of Applied Informatics, University of Macedonia at Thessaloniki, Greece. To end with, the results of using educational game as a supplementary tool in traditional education are discussed and conclusions are drawn.

Literature Review

Research has shown that young people and students of today spend a lot of time engaged with technology, including, but not limited to, television, movies, video console games, computer games, Internet surfing, instant messaging, e-mail, and downloading music (http://www.mediascope.org).Students today, have different learning needs from previous generations and for this, schools need to incorporate more sophisticated technology into the learning environment. Experts in the field suggest that the use of games and simulations, accompanied by thoughtful pedagogical skills and strategies, will do much to increase concentration and engagement. Games and simulations require students to build knowledge for themselves while interacting with peers. This kind of learning is now being seen as a valid, pedagogical method falling under the umbrella of 'constructivist learning theory.' Constructivism allows the learner to acquire knowledge by seeking it out and actively constructing it as opposed to being a passive receiver of information. Constructivist learning theory is based upon the research and writings of theorists such as Piaget and Vygotsky (Ibbitson, 2005).

Educational Game

An educational game is a computer-assisted instructional technique in which skill and chance are combined for practice on previously taught information. Sauvé et al. (2005) define an educational game as an artificial situation (fictitious, fanciful) in which a player or players are put in a position of conflict (struggle confrontation), at times one being set against another competition or, at times, players being allied against other forces (cooperation). The game is governed by rules (game movements, game control and game over) which structure players' actions with one aim in mind: winning (winners vs. losers), being victorious (overcoming chance, beating the computer, one or several players) or defeating an opponent, all while learning. A game or simulation has several levels of varying degrees of difficulty through which the players "move" and gain new skills and strategies in order to win the game. The game also adapts to a player's level of ability so that the player finds him/herself in a zone of being continually challenged. Games are often social in their nature and can involve many players 'networked' together. DeKanter's (2005) result is what some experts have called a constructivist learning environment which weaves together the essential and interdependent ingredients for productive learning.

For understanding learning as participation in social practice, Begoña (2007) suggests ways for educators to transform game playing into participation in social practice. Shaffer et al. (2004) suggest that when players immersed in a simulated game environment as a group, develop their own set of understandings, practices, identities and values. They become a 'community of practice' that has its own way of thinking and acting. They call this way of thinking within the community the 'epistemology of practice' and suggest that when

individuals become a part of the 'culture' of the game, their knowledge skills, identities and values are shaped by a particular way of thinking into a coherent 'epistemic frame'. Prensky (2005) indicates that complex games "require a player to learn a wide variety of often new and difficult skills and strategies and to master these skills and strategies by advancing through dozens of ever-harder levels. Doing this often requires both outside research and collaboration with others while playing".

Teacher's perceptions are critical to the success or failure of integrating computer games with educational features into classrooms. Can and Cagiltay (2006) conducted a study among Computer Education and Instructional Technology (CEIT) departments. The results of the study reveal that the prospective computer teachers, who participated, have positive perceptions regarding the use of computer games with educational features in education. Moreover, most of the participants plan to use such games in their future professions. However, some of the participants have doubts, especially concerning the issues of classroom management and the educational effectiveness of computer games currently on the market.

Educational Game Central (EGC)

The phrase 'Simulation and Advanced Gaming Environments' (SAGEs) reflects transformation that is taking place as games and simulations incorporate new technologies (Kaufman and Sauvé, 2005). A simulation is a game that simulates a real life scenario. Simulations let players participate in a new world—they can inhabit a role that would otherwise be inaccessible to them and such simulations are powerful contexts for learning. Rather than simply looking at words and symbols on a page, players can experience the reality that words and symbols describe (Shaffer, Squire, Halverson and Gee, 2004).

Savie's online Educational Games Central (EGC) was designed as a virtual meeting-place for those interested in using games for educational purposes. Teachers can choose between either using predefined available games or creating new games from scratch. (http://www.savie.qc.ca/carrefourjeux2). A *frame game* (design environment) or an "empty game" is a teaching tool endowed with a structure that generates learning activities, promotes the use of various strategies and involves conflict. Also, it provides a set of rules governing players' movements and criteria which allow players to end the game by declaring a winner. The *content* refers to the information conveyed during the game. At the moment there are six user-friendly generic shells (*Snakes and Ladders, Tic Tac Toe, Trivia, Mother Goose Game and Concentration, Parcheesi*) and they were developed for the on-line modification of learning content (Sauvé et al., 2005). In this way, teachers need to add the content based on predetermined objectives to generate a new educational game adapted to their audience.

Virtual Classroom

Virtual Classroom Live eLearning or Synchronous eLearning is a group of students gathered together online at a certain time, for a certain duration; students are in different places and are taught electronically by a teacher using a web browser with integrated voice and video as the main delivery medium. As the sessions are recorded, the learning module can be both synchronous and asynchronous. It can be replayed for clarification and reinforcement (Keegan et al., 2005). One of the biggest advantages of the virtual classroom is the opportunity that it gives to the students in encouraging them to become autonomous. Aydin (2006) in his research concludes that the virtual classroom application facilitates increased authentic interaction and allows greater learner autonomy. Also, shy students participate in the lesson easily when they do not feel spotlighted as in a traditional classroom (Aydin, 2006). Chou and Liu (2005) conclude in their study that students' learning in a technology based virtual learning environment have better learning effectiveness than their counterparts in traditional classrooms. CENTRA is an online learning environment with virtual classroom interaction. It is a set of features for interactive, effective group learning, bringing together voice, video, data and graphics in a structured online learning environment for up to 500 simultaneous users (www.centra.com).

Research Methodology

In Higher Education the most common way of teaching practice is still focused on transmissive rather than interactive strategies to support learning. In order to support our students' studying and learning, we piloted educational game as a part of our blended learning approach during the first semester compulsory course "Algorithms with C". The blended learning approach was firstly implemented during the academic year 2005-2006 for a unit of the course (Papadakis, Paparrizos and Rossiou, 2006). Last year, this approach was implemented during the first semester. Students (33 out of 187 of the registered students) participated

voluntarily. The main aim was students' support during their studies of algorithms with the use of e-learning tools (synchronous and asynchronous).

The traditional classroom learning was not replaced by e-learning part but it was a natural extension of it. Traditional teaching process supported by Tutoring Tele-Meetings (TTMs) and included various media, such as: stand-alone web-based learning (Learning Management System for studying educational material), asynchronous (forum and webcasts) and synchronous (virtual classroom, educational games) web-based teaching. One of TTMs aimed to help students cover their gaps in recursive algorithms and an educational game was used in the context of that TTM.

The Experiment with the Educational Game

We adopted the generic Snakes and Ladders shell of Simulation Advanced Game Environment to create *Algorithms_Recursive* game (Figure 1). Forty four (44) questions of three (3) levels of difficulty covered various aspects of recursive algorithms. They aimed to revise "recursion" and develop critical reflection on what they have learned and what they have not consolidated sufficiently.

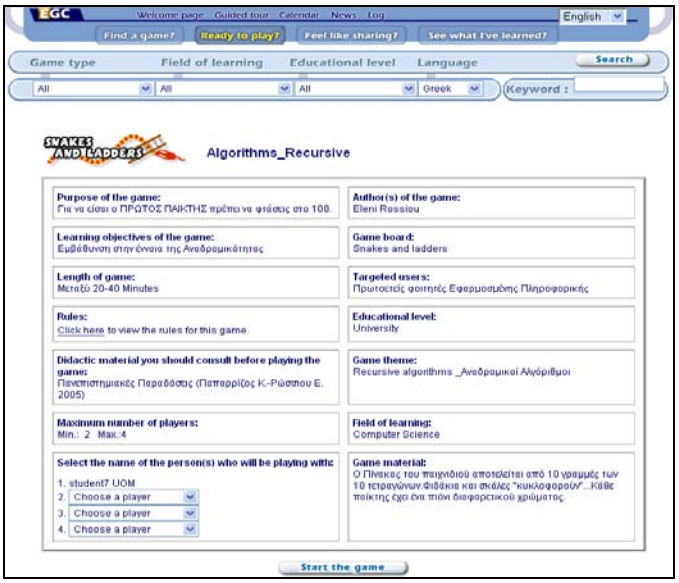

Figure 1: Snakes and Ladders Algorithm Recursive Game (properties of the game)

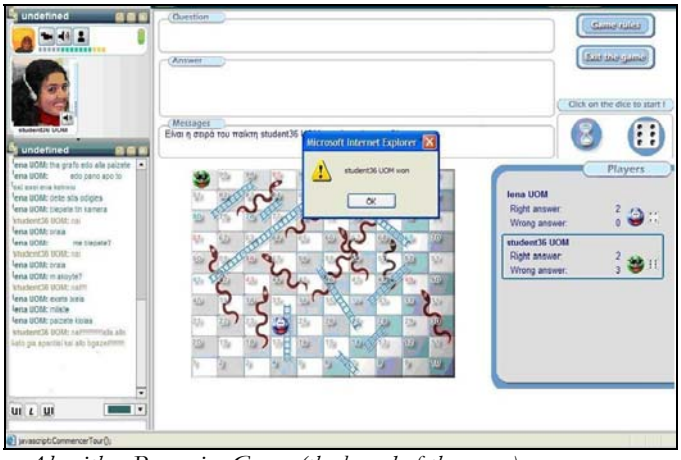

Figure 2: Snakes and Ladders Algorithm Recursive Game (the board of the game)

The students played in pairs. During the game, each student rolls the dice; whoever gets the highest number begins the match and each one takes a 'turn'. *Players* put their tokens at the start. Token moves according to the number indicated on the dice. If the number is six, the player rolls the dice again. If a player arrives at the bottom of a ladder or at the head of a snake, a question is displayed. If player answers correctly, his or her token moves up, at the top of the ladder or stays at the head of the snake, accordingly. Otherwise, the token stays at the bottom of the ladder or moves down to the tail of the snake. The first player who arrives at the square 100 wins the game (Figure 2).

Data Collection

Two tools of data collection were used: a) a 14-item survey instrument and b) semi-structured interviews. The purpose of the survey was to gain a better understanding of students' learning preferences for their studying support in relation to on-line educational game environment, in order to redesign their learning environment according to their learning needs. Our empirical study was based on questionnaires and interviews, which included quantitative and qualitative topics. At the end of the semester, the survey was administered to thirty-three (33) first year students who participated in at least one TTM (focus group). The survey instrument had a 100% return rate. More data were elicited from focus group interview with the virtual class instructor. The focus group survey contained open-ended questions asking students to verbalise about their learning experience, their preferences and the impact of the online game support on their learning. It was an investigation of students' experiences and attitudes on the utilisation of the game included the utilisation of tele-education methods as an additional tool in the traditional higher education. Students were asked to answer to questions divided into three parts: the technological part, i.e. the difficulties that they faced up during their access to the platform of the game, the pedagogical part that focused on the game itself (educational goals, students' perceptions, feelings and motivation) and the cognitive part which focused on the recursive algorithms learning.

This paper presents findings on: a) easiness (or not) of the implementation of a web-based game as an instructional technique in higher education (b) the effectiveness of the game in students' studying and motivation during the semester c) students' perceptions and attitudes on the ability of educational games use to enhance learning d) the changes in teachers' role due to preparing and implementing teaching by playing.

Participants

In our empirical study the focus group consisted of 33 students enrolled in the "Algorithms with C" course who had voluntarily participated in at least one of TTMs. The blended approach study lasted 14 weeks and it was implemented complementary to 2 hours f2f lecturing. The game of recursive algorithms took place during the TTM and it was available for 4 weeks with one more game for revising *sorting algorithms*.

Results

The data collected in the survey provided information about effectiveness of educational game for students. Based on the students' feedback, a short statistical analysis was carried out, in order to clarify the benefits or the drawbacks of educational game use in blended learning approach.

Findings

In this subsection, we present our findings about students' and tutors' perceptions and attitudes after their experience of playing a web-based educational game.

As it concerns the difficulties that students faced up during the game more than half of them (62,5%) found difficulties in accessing the platform and many found the access very difficult (Figure 3). The instructions of the game helped students to play since they found them clear (50%) or very clear (25%) but a significant number of students (1/4) found them not so clear.

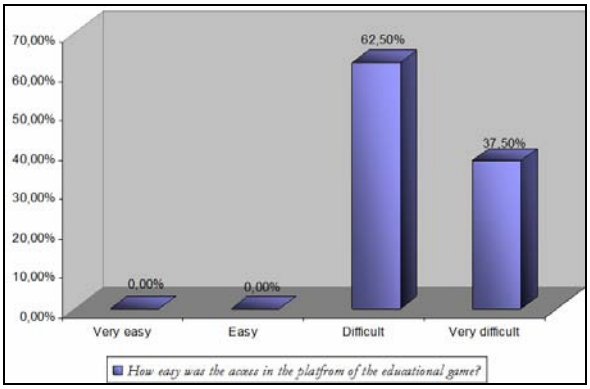

Figure 3: Easiness of accessing the game platform

More than half of the students (62,5%) asserted that their knowledge on algorithms developed a lot or very much and can distinguish a recursive algorithm and its elements easily or very easily. It is worth to refer that none of the students affirmed that there is no cognitive growth on recursive algorithms (Figure 4).

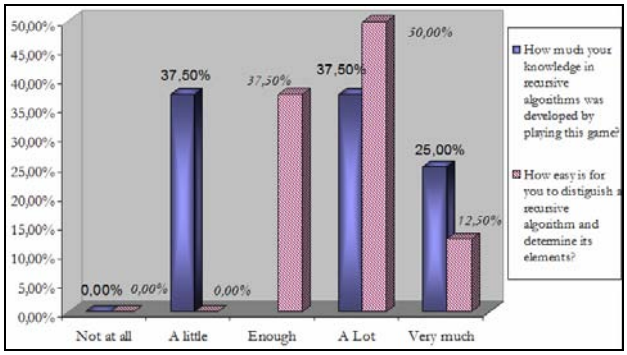

Figure 4: Game effectiveness game in learning recursive algorithms

As it concerns the achievement of the educational goals and the motivation that the game caused, the most of the students (87,5%) considered that the goals were successful and none of the students judged that educational goals were failed (Figure 5).

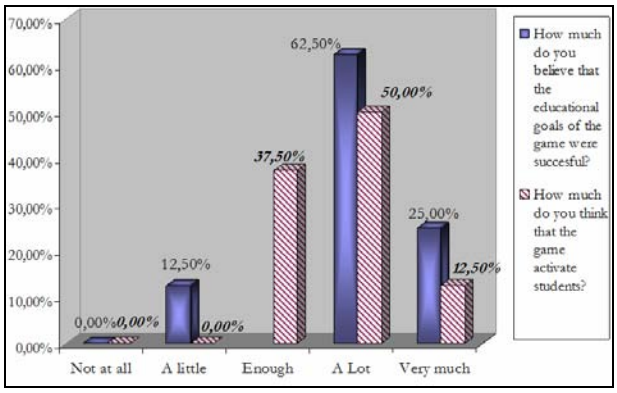

Figure 5: Success of goals and students' motivation

Six months after the end of the course, a TTM, which aimed to evaluate TTMs of the previous semester, took place. In the interview students expressed their miss of TTMs and educational games since this does not happen in other courses. Especially, they answered to various questions of the semi-structured interview.

In the question: *"For which reasons would you prefer to replay (or not) an educational game from distance?",* all students answer that they would like to replay and the common reason to all answers were that "It is more effective learning by playing" or "it is fun to learn by playing". Some other reasons are because of: "entertainment and simultaneous learning and comprehension of the new concepts in depth", or "being able to see if there are still problems at this particular topic (recursive algorithms)" or finally, "because of having the opportunity to find points of misunderstanding with a fun way and communicating with my colleagues and not with the traditional boring way of self studying the books!"

A student stated: "*Educational games is an unprecedented experience for a first year undergraduate and combine with a unique way knowledge and entertainment*" All the students agreed with it and they added statements like: "This way of teaching is unique because it is veered from trivial teaching and it is an amused way for students to self-evaluate themselves" or "through educational games students can play and not only entertain themselves but also learn by their mistakes and furthermore by other students' mistakes. If students make mistakes they can remember them and not repeat them".

In the question *"How did you feel when you lost or won the game? Is it significant for you to win and how much?",* the most of the answers included: "I felt very happy" and "No, it is not significant. The important thing is that we played" or "there is no so importance in winning but more in playing. It was a unique experience" or "I won and I felt that I won because I knew a lot of recursive algorithms". Another student said "I lost! It was not too important to win but I felt disappointed because I 'discovered' the gaps that I had in recursive algorithms.

But from the other side, this was good and very useful because I emphasised my study on them during the examination period".

As it concerns *tutors' perceptions* about their role, their experience illuminated that the scientific knowledge in the taught subject is not enough. Their familiarisation with web tools (email, internet, online communication and virtual class) was required. Also, since computers lead to personal learning (Gell-Mann, 1996), they developed their abilities in controlling students' learning according to "class" needs and on preparing the appropriate material for the educational game. They needed to be enriched with instructional design and pedagogical and e-learning principles. And apart from all above, it was required a lot of time to keep students active and prepare suitable attractive educational game.

Tutors followed Lehman's (1999) guides that the instructors should feel themselves very comfortable with the new technology and the new medium for focusing on the instruction only. They used the proposed three activities which helped them to feel comfortable: a) knowing the components of the new environment, b) discovering the differences between the traditional classroom and the new interactive environment, c) practicing with the new tools.

Discussion

An interesting research question is related to the effective use of educational game complementary to f2f teaching in conventional Higher Education. In this subsection, we present some new results on the students' perceptions regarding to the above question. It is our belief that our results constitute a big step towards this direction. Our findings showed that the web-based platform of educational game was quite difficult to be accessed. This mainly happened because our students were first year undergraduates and unfamiliar with messaging pop-up windows that displayed (for example the message about installing the necessary software for playing java applets). As players said, six months after the end of the course, they don't have problems any more in accessing the platform since they understand the displayed messages. The effectiveness of the game was spread to various aspects: from reforming students' perceptions and attitudes towards the use of an extraordinary instructional technique to support students' studying. Also, a clue if not a proof about the comprehension in-depth of recursive algorithms due to the game is the fact that players marked higher (the average mark of the focus group denotes that they answered 65% of the recursion question correctly vs. 40% of the control group). So, players had bigger success in exams and this is also a reason that students-players recommend the future students to participate in game activities.

Although teachers and students agree that the use of educational games needs a lot of time for both of them, they accept as true the high effect of this innovative instructional technique and they prefer learning by playing. All the above are tutors' motives to adapt themselves in the new role that they gain due to the students of today who belong to the generation that has been grown up with new technology. The scientific knowledge in the taught subject is not enough since tutors heavily felt that their role as transmitter of knowledge has been transformed to guidance, advisory, coordinative, promotional. Their familiarisation with e-tools, abilities development in controlling their class according to learning needs and their enrichment with theoretical background of instructional design and pedagogical e-learning principles were some of the requirements that had risen up. As Harper et al. (2004) say, there is a connection between pedagogy, personal experience and distance learning. When a teacher is somewhat reluctant to use technology or views it in a negative way, pedagogy may suffer. The method of introducing computers to faculty is another factor in the personal development of technological pedagogy. It is imperative that the pedagogy continues to evolve and grow as technologies change (Harper, Chen, and Yen, 2004).

Conclusion

There are not enough studies about learning acquisition through online games in tertiary education. This paper examined the use of on-line educational games during synchronous virtual classrooms in Higher Education to enhance engagement and learning. Today's generation of students learn differently than previous generations. Shaffer et al. (2004) argue that "most educational games to date have been produced in the absence of any coherent theory of learning or underlying body of research".

Constructivist learning is a current educational trend and distance internet games are now being viewed as an excellent vehicle for constructivism. Games are not meant to replace current pedagogical methods but rather are seen as a complementary tool which is based on those methods. There are a few ready educational games offering educational content which meet the specific educational and technological criteria expected by

instructors. SAVIE offers a new way with which educators are able to create new games and develop their on-line game adapted to their students' needs.

The scientific contribution of our case study is the presentation of some new results students' adaptation of web-based and distance educational methods and especially the adaptation of educational games although they are only first year students and so, unfamiliar and hesitated in using e-tools. The students' positive attitudes in using synchronous educational game complementary to f2f traditional lecturing seem very promising for the improvement of academic studies in the future. Students' perceptions, regarding learning recursive algorithms in more depth, can be used as a guide for improving teaching and learning of algorithms in Higher Education.

Since instructors try to improve the quality of academic studies in Universities, our findings constitute a step towards to this direction and it is for sure that educational games should be expanded and support Higher Education. Another future work is to try to identify the students' perceptions on implementing the web-based to other courses (both theoretical and/or laboratorial courses). Also, a possible future research direction is to find ways to improve the first year students' participation in "learning by playing".

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