Serious Computer Games Design for Active Learning in Teacher Education

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Abstract. Active learning is a pedagogical method that focuses the responsibility of learning on learners. They engage in activities, such as reading, writing, discussion, or problem solving that promote analysis, synthesis, and evaluation of class content. Cooperative learning, problem-based learning, and the use of case methods and simulations are some approaches that promote active learning. Serious games design can provide a framework to support confirmation, structured, and guided inquiry. There is a convergence between the core elements of a good serious game design and the characteristics of productive learning. Another link between games and learning is formative feedback as a critical part of any learning effort and a key component in game design that adjusts challenges.

Keywords: Serious games design · Active learning · Learning goals · Teacher education · Information-communication technology · Formative feedback

1 Introduction

Learning in schools is still heavily geared toward the acquisition of content within a teacher-centered model, with instruction too often abstract and decontextualized and thus not suitable for this age of complexity and interconnectedness. This is especially topical for "*digital generations"*, born after 1985. They grew up surrounded by digital media, and most of their activities dealing with peer-to-peer communication and knowledge management, in the widest sense, are mediated by these technologies. The changing ways of how members of this generation learn, communicate, and entertain themselves are the primary reasons behind the growing popularity of social computing applications, sociability, and team spirit, engagement and working attitude, multitasking, individualization and personalization, immediacy, and fluency with multiple media types [11, 13]. But these generations are also called "*gamer generations"* as they spend a lot of their time playing computer games. And as there are many connections between games and learning, educators could integrate games into teaching and learning. Game design has a lot to teach us about learning, and contemporary learning theory has something to teach us about designing better games [18]. Marshall McLuhan, famous Canadian philosopher of communication theory, who predicted World wide Web in sixties, when he talked about a "global village", stated: "*Anyone who makes a distinction between games and learning doesn't know the first thing about either*."

C. Vaz de Carvalho et al. (Eds.): SGAMES 2015, LNICST 161, pp. 94–102, 2016.
DOI: 10.1007/978-3-319-29060-7_15

Games can lead to changes in attitudes, behavior, and skills and that is actually exactly that how *learning* is defined. We need to explain why game-based learning is engaging and effective and when, with whom and under which conditions games can be integrated into learning.

There is a convergence between the core elements of a good game and the characteristics of productive learning [17]. The constructivist problem-based and active learning methods indicate the success of learning in the context of challenging, open-ended problems. Goal-based scenarios have long been viewed as an active primer for situated learning. Correspondingly, in a good game a player is involved in an iterative cycle of goal-based, interactive problem solving. Another link between games and learning is formative feedback - a critical part of any learning effort [16], and also a key component in good game design that adjusts challenges and gives feedback so that different players feel the game is challenging and their effort is paying off. Well-designed games have the potential to support meaningful learning across a variety of content areas and domains. But all games are not good for all learners and for all educational goals!

Gee claimed [4] that the secret of a good game was not its 3D graphics with bright colors and exciting sounds or music, but its underlying architecture where each level is adapted to the outer limits of the player‘s abilities, seeking at every point to be hard enough to be just doable. Cognitive psychologists have long claimed that the best instruction hovers at the boundary of a student‘s competence. And why aren‘t the games used more widely in classrooms if they are so useful for learning?

While time constraints, cost and availability of appropriate games, and a lack of knowledge about their integration into learning are possible reasons for this, the major problem is the lack of good research on games and learning [19]. Compared to other types of instructional systems, there are too few experimental studies examining the range of effects of gaming environments on learning, and a corresponding lack of theory and practice for their design and implementation.

2 Game Based Learning

In modern education there is a need for shift from traditional didactic transmission models of teaching to the learner-oriented active forms of learning whereby the teacher’s role changes radically. Instead of transmitting knowledge, teacher prepares the appropriate environment with different challenges and tasks for independent student learning, guides them and gives them adequate feedback. Learning objectives move from the lower taxonomic levels, which are dominated by recalling information or retrieving various data and facts, to higher taxonomic level, where the focus is on the search for, evaluation and use of knowledge in new settings.

Game is a structured or semi-structured context that looks familiar and relevant and where players find goals that they try to achieve by overcoming challenges. When appropriate learning goals are integrated into game activities, the game can become a learning tool that integrates most of the requirements for modern learning [5].

Prensky [12], Gee [4], and Whitton [20] defined game based learning as *a process of learning with the use of digital games*. Students are directed toward a goal, choosing

actions and experiencing the consequences of their activities. They make mistakes in a risk-free setting, and through experimentation they learn actively and practice the right way to do things. They can be additionally stimulated by instant feedback and reward of success. Students remain highly engaged in their activities and cognitive processes that can later be transferred from the game environment to real life. Next to the environment, where learning takes place, games usually provide also motivation, which has many effects on students' learning. It can direct activities toward particular goals, lead to increased effort and energy for learning, increase persistence in activities, affect cognitive processes and enhance performance [9]. All these characteristics increase the chance that the desired learning outcomes will be achieved.

Learning is defined as the activity or process of gaining knowledge or skill by studying, practicing, or experiencing something. As we have just stated, playing games can be an efficient way to learn [10, 21, 22]. But what are the key elements of a good serious game?

Gross [6] stated that serious games must have well defined learning goals and have to promote development of important strategies and skills to increase cognitive and intellectual abilities of learners. According to Malone [8] and Garris [3], the elements contributing to educational values of digital games are sensual stimuli, implemented as visual and audio representations of learning material, fantasy (context presented in imaginary setting), challenge (demanding or stimulating situation) and curiosity (desire to know or learn).

These elements must be integrated into the environment with well defined objectives and rules, the context of meaningful learning, appealing story, immediate feedback, a high degree of interactivity, challenges and competition, as well as random elements of surprise. Games can be social environments, sometimes involving large distributed communities. They imply [1] self-learning abilities where players are often required to seek out information to master the game itself, allow transfer of learning from other realities, and are inherently experiential with the engagement of multiple senses.

Van Eck [19] states that games can be effective learning environments not just because they are fun but because they are immersive, require player to make frequent important decisions, have clever goals, adapt to each player individually and involve social network.

Garris [3] argues that in good serious games instructional content is blurred within game characteristics. Students are playing the game and having fun, forgetting about the "learning" part of the experience even though they are constantly presented with new concepts which they have to adapt in order to be successful in game. More detailed overview of the important characteristics of good serious games can be found in the paper by Zapušek and Rugelj [22].

3 Serious Games Design in Teacher Education

Rieber, Smith and Noah [14] stated already in 1989 that there are two distinct applications of games in education: game playing and game designing. Game playing is the traditional approach where one provides ready-made games to students. Game designing

assumes that the act of building a game is itself a path to learning, regardless of whether or not the game turns out to be interesting to other people. The idea of "learning by designing" is based on the assumption that active participation in the design and development process is the best way to learn something. This approach has gained increased prominence due to the proliferation of computer-based design and authoring tools.

At the Faculty of Education, University of Ljubljana we started to implement this approach six years ago in the framework of the two-semester course *Application of ICT in education* for future computer science teachers. There have been a lot of different approaches, methods and ideas developed on how to organize the process of designing and developing educational game from the initial idea into to final product. We could not agree completely with any of them so we decided to develop our own method, called 'SADDIE' [15]. In the following years, we have spread the use of this method to several elective courses at our university, to a course at the University of Rijeka, Croatia, and to postgraduate international summer schools on game based learning that took place in Spain, Estonia, Ireland, Bulgaria and Slovenia.

SADDIE is an acronym of six main project phases: Specification, Analysis, Design, Development, Implementation, and Evaluation. SADDIE is an extension of 'ADDIE' instructional design approach that was developed at the Florida State University in the seventies and was used for designing learning materials for American army [2].

3.1 SADDIE - Methodology for Serious Game Design

The main focus of our approach is project based active learning, where students working in small groups are highly motivated in game design and production. They compete against each other, which team will produce the best serious game, what is seemingly the main goal of their activities. But this is actually only a side effect. The two main learning goals of this process are to learn in an efficient way through carefully refined process of active engagement in the game design and production process and to improve the key teachers' competences. They include the ability to determine learning objectives that are in line with the syllabus, the selection of appropriate teaching approaches and their implementation in learning process, preparation of feedback, evaluation of acquired knowledge and evaluation of the learning process.

Serious games design is implemented as a project in a course with a total of 8 ECTS credit points. In accordance with the provisions of the European Credit Transfer System students are supposed to spend between 220 to 240 h in the project activities. Course syllabus states that its main leaning goal is to summarize all didactic and technical knowledge that students acquired during their studies at the faculty and to apply it in a relatively complex project on instructional design. The course is based on the constructivist learning theory and has consequently very limited number of traditional lectures. In the introductory phase of the project lecturer presents main project requirements and defines some general rules about the learning goals and about organization of work in a project. Students get familiar with 'SADDIE' methodology that defines main project phases and other incidental activities.

Students work in groups of 3 or 4 students, which are set up according to their preferences. They are supposed to organize all activities in the project by themselves.

They are free to define different types of organizations of work and to accept different roles in the project. Later, during the run of the project, students in project groups write a log in which they report on the dynamics and organization of the work of the group. By analyzing the logs, we found that in some groups there were exposed leaders and in the others the responsibility was evenly distributed among all members.

At the regular weekly meetings groups prepare oral reports on the work in the past week and on any problems they have encountered. They receive immediate feedback from peers and from the teacher. If difficulties arise, the teacher initiates discussion about what could be the reasons for a problem and gives some hints or suggests possible ways to solve them.

3.2 Main Project Phases in SADDIE

As we have already mentioned, SADDIE methodology for serious games design and development consists of six main phases [15].

Specification. Specification is the initial phase of game design process. Students are supposed to choose the topic from the computer science syllabus for primary or secondary school, which is complex and challenging for the students, and consequently difficult to understand. Students have some experiences about such topics as they had four weeks of teaching practice in schools in the previous semesters. They have to consider if students could benefit from presenting the topic in a game format as game based learning is more time consuming that traditional learning and can only be justified when learning goals can not be reached otherwise. Students have to set didactic foundations for later stages of the project at this point and to define roughly some basics game elements such as time and place of the events, characters, artefacts, challenges, rules, and goals. Game should be funny and should provide competition or conflict.

After the initial phase students have to submit a document that contains a short presentation of the selected topic from syllabus with the arguments for the selection, a brief description of a gameplay, a list of specific learning goals from the official curriculum, motivational elements, specific game mechanics and didactical methods for achieving learning objectives, the methods for assessment of learning, tools for communication and collaborative work, and the suggestions for implementation of game into learning process.

Some examples of the selected topics in the previous years are binary numbers, arrays in programming language, the importance of sub-programs in programming, complexity of selected sorting algorithms, structural components of personal computers, rules of netiquette in the Internet, and Internet security threats.

Analysis. The analysis phase focuses on analysing the specification and preparing all the information needed for implementation phase. First decision is to select the target audience for the game that directs the choice of game story, level of difficulty, graphics, characters, interface, type of interactions and gameplay itself. Students have to consider available resources for implementing their ideas and make compromises. This includes selecting appropriate game engine, software for creating visual and audio artefacts and

animations. Students have to focus on defining expected taxonomic levels of knowledge for selected learning goals. This is followed by the most important stage of analysis phase where learning goals are mapped onto game goals. It is crucial to include learning content in the game so that important elements are not lost and that the activities in the game do not override learning objectives. Objectives of the game should support an understanding of the main concepts in a different, more interesting way, which is familiar to the players and as such can facilitate the construction or transfer of knowledge. Progression throughout the game is possible only if player properly understand the concept behind game goal.

Design. The goals of a game can be associated with different types of knowledge. We are using the Kapp's taxonomy [7] that defines the following categories: declarative, conceptual, and procedural knowledge, knowledge based on rules and some other, so called 'soft skills'. Each goal of a game is evaluated based on this classification and incorporated into the story. Detailed scenarios are prepared in the design phase, with dialogues that integrate the requirements and recommendations from the specification phase. Students are then required to design all the graphical elements needed for the games, such as the backgrounds for the scenes, the artefacts, and all characters. They are also encouraged to record speech, sounds, and music for the game and to make simple animations.

Development. In the development phase, a game is produced with the selected game engine. When we started with educational game projects five years ago, students had to implement their own game engines with Actionscript 3 and produce the final product. We noticed that they spent a lot of time and energy on programming, so they couldn't focus so much on the content and didactical challenges. Our idea was to find the most appropriate game engine that would ease and fasten the development process. We decided to choose the e-Adventure platform, which has been developed in a research project aiming to facilitate the production of educational games at the Universidad Compultense de Madrid. It provides efficient tools for developing complex adventure games with just basic understanding of programming.

Implementation. Implementation phase defines various possibilities on how to incorporate learning with educational game into a learning process. Students have to consider different options and write specific proposals for teachers. It is crucial to find reasonable situations where learning outcomes can hardly be achieved using traditional teaching methods. Usually different accompanying activities need to be prepared as a learning package. Students carry out all these activities during their practical training in schools.

Evaluation and Testing. The evaluation phase is taking place in parallel with the implementation or immediately after this phase. Each project group prepares beta testing that is carried out by their peers. This is followed by gamma testing during their practice in primary or secondary schools. Students measure the efficiency of the alternative learning approach, comparing it to the traditional one, and they get feedback from the players and from teachers. This allows them to find out whether the objectives from specifications have been achieved and to improve the quality of their products.

3.3 Achieving Teaching Competences

SADDIE method is designed to stimulate improvement of different teaching competences in the courses in teacher education study programs through instructional design process [15]. Students achieve *didactic competences, technical competences,* and essential *skills for teamwork*. Didactic competences consist of reflective consideration on selection of learning goals, classification of learning goals according to taxonomic levels and type of knowledge, selection of appropriate activities for knowledge construction on selected taxonomic level, identification of suitable concept behind learning objective, ability to map the core idea into another context, and provision of proper feedback. Students also get familiar with the methodologies for evaluation of their work, acquired knowledge, and learning process.

Another key issue is the integration of serious game into teaching and learning process. Method of incorporation of games into the learning process depends on several factors and is specific to each game. The general problem is that the time available for a gameplay is limited. Therefore, it makes sense to use games only in the cases where it is difficult to achieve learning objectives with traditional methods. Students often then play serious games at home. It is very important that after such "homework" teachers plan appropriate reflection activities in the classroom. Without such activities in game-based learning does not lead to the expected results.

The activities in the framework of SADDIE process are not focused on technical aspects of a game design, but students usually become motivated during their project activities and they individually, with some support from teaching assistants, learn about animation, manipulation of visual materials, recording and editing music and other sounds, drawing in perspective, and learning more advanced programming techniques in order to make their projects more interesting.

The ability to work in a team is a relevant competence nowadays. It is very important for teachers to have this competency and that is why we pay special attention to it. Groups report on their collaboration experience in weekly meetings and all important activities and reflexions are collected in the log, which is written by each group during the project.

4 Conclusions

Active learning approach based on serious game design has been developed at the Faculty of Education, University of Ljubljana. Teacher students in the fourth year of the undergraduate study program *Two subjects teacher* design in develop educational games in small groups in projects that are carried out in the framework of the two-semester course *Application of ICT in education*. The methodology for this approach has been developed and its application in the last six years had various positive outcomes. Serious games as final products are just a side effect of the more important goal, i.e. achieving different competences that are essential for modern teachers. Vital teachers' competences include the ability to define learning goals that are in line with the syllabus, the

choice of suitable didactical methods and their inclusion in the teaching process, development of a game, preparation of response for students, evaluation of acquired knowledge and of the learning process, independent planning and organization of all necessary activities in a project, and the ability for teamwork.

We have spread the use of this method to several elective courses at our university, to a course at the University of Rijeka, Croatia, and to postgraduate international summer schools on game based learning all around Europe.

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