GAME-BASED LEARNING AND GAME CONSTRUCTION AS AN E-LEARNING STRATEGY IN PROGRAMMING EDUCATION

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ABSTRACT

A strong trend in the 21st century has been the transformation of traditional face-to-face rostrum teaching to blended learning in online learning environments. There are several research studies describing that these new virtual learning environments can leave learners in a state of loneliness and boredom resulting in low motivation and high drop-out rates. In studies of programming education there have been frequent reports about high drop-out rates and poor outcomes.

This study analyses and discusses a distance course on multimedia programming where the authors have been subject matter experts and content developers as well as teachers and facilitators. Practically everything in the course activities is built around game analysis and game construction including a final project where students design and implement their own educational games. Main didactic approaches in the course are constructionism, game-based learning and multimodality. With a case study approach data was collected from course documents, evaluation questionnaires, students’ games and online discussion fora.

Findings indicate that game-based learning (GBL) can be a catalyst creating energy and motivation especially for students in the digital natives generation. The idea of game construction with multimedia in open assignments might also be a way to increase pass rates in programming courses at university level. Furthermore, multimodality in course content and course activities seems to be a promising concept and not only for programming courses. However, the described combination of GBL and multimodality is no silver bullet, and rather just one e-learning strategy worth combining with others.

KEYWORDS: Constructionism, E-learning strategies, Game-based learning, Game construction, Multimodality, Programming education

1. INTRODUCTION AND AIM

University courses on computer programming have in several studies been identified as a problematic area with high drop-out rates and low learning outcomes (Guzdial, Soloway 2002; Lahtinen et al., 2005; Mozelius, Olsson, 2015). It has been pointed out that students not only have problems to understand theoretical concepts but also to get started in code construction and to learn the basic programming techniques (Eckerdal, 2009). Furthermore, research studies have reported about low pass rates in combination with students lack of motivation (Jenkins, 2002; Wiedenbeck et al., 2004; Mozelius, Torberg, Calderon Castillo, 2015). This is an identified problem in traditional face-to-face courses but with new additional pedagogical issues in online virtual learning environments.

A clear trend at universities in the 21st century has been the transformation of traditional face-to-face rostrum teaching to blended learning or pure distance education in virtual learning
environments (Graham, 2006; Lim, Morris, 2009; Park, Choi, 2009). Several research studies describe how these new virtual learning environments can leave learners in states of loneliness (Brown, 1996), confusion (Hara, Kling, 2000) and boredom (Keller, Suzuki, 2004) resulting in high drop-out rates (Park, Choi, 2009).

The generation entering university programmes today is the first generation that have used Internet and computers since their early childhood. They have in research studies been called The Digital natives (Prensky, 2001), The Net-generation (Spires, 2008) and Generation Y (Mozelius, 2012). Whatever used term, the vast majority have excellent basic computer skills, are comfortable with online environments and regularly playing digital games with sophisticated user interfaces. They have often started to play games at an early age and they spend considerably amounts of time playing various kinds digital games (Mozelius et al., 2015), and also so called educational games and serious games (Mozelius, 2014).

Sweden is a connected and gaming country where around 50% of the two year old kids have been on the Internet to play games and watch films Swedish Media Council (2015). Digital games can have a stimulating impact (Wiklund, Mozelius, 2013), and game-based learning (GBL) is seen to support active learning and foster creativity (Gee, 2014). Furthermore, game-based learning can reinforce motivation among students who have lost their motivation for traditional learning (Wiggins, 2016).

1.1 AIM

The aim of the study is to analyse and discuss how game-based learning and multimodality can be used with a constructionist approach to stimulate and motivate students in online programming courses.

2. Extended Background

One of the more difficult aspects in the learning of programming is to learn syntax and to understand coding concepts. There are many ways to achieve this and what in one situation is the best practice does not necessarily work well in another situation. To learn to program also requires to be able to see the big picture and to develop a deeper understanding of structures and programming techniques which usually comes over time after hours in of coding and seldom immediately. Motivation and variation are important factors if learners should be able to sit and concentrate for hours of practical coding.

In the traditional classroom students often are fed with information and with a risk of cognitive overload. This paper will describe and discuss how programming might be taught in online environment with a strategy that combines game-based learning and multimodality in a constructionist approach.

2.1 Games and Game-Based Learning

Humans have been playing and gaming for millenniums (Huizinga, 1938) and we are today still playing the board games that were invented in Mesopotamia, ancient China or ancient Egypt (Bell, 1969). Games like Kalaha, from the Mancala game family, was played in Egypt as early as
in the period between 1500-1150 B.C. (Barnes, 1975) and Chess/Chaturanga also have a long and well-described tradition (Murray, 1913).

The concept of using games like chess in educational contexts has been around for long, but the birth of digitalized games started a renaissance for this idea in the 1980s when Thomas Malone (1981) did an analysis of why digital games are engaging and motivating. In his findings there were three important key components: challenge, curiosity and fantasy. Another early pioneer studying how games might stimulate learning and motivation was Mark Lepper. Later Lepper and Malone compared their findings and created the *Taxonomy of Intrinsic Motivation*, where the concept of intrinsic motivation is divided into the levels of internal motivation and the level of interpersonal motivation (Malone, Lepper, 1987).

As a didactic approach game-based learning was introduced at university level in the 1970s by the constructivists Jean Piaget (1973) and Lev Vygotsky (1978). These contributions could be seen as a continuation of the more general discussions on the human need of play that was started in 1938 when the Dutch cultural theorist Johan Huizinga presented his ideas about mankind as *Homo Ludens* or Playing Humans. (Huizinga, 1938). In Huizinga’s book play is described as a central cultural phenomenon essential for most human activities. Huizinga’s concept of Homo Ludens is built upon the idea of naturally playing humans with play as a prime drive in culture activities. This is an idea that can be traced back to the romantic era where the essential human play drive (spieletrieb) with human beings as fully human only when they are playing was introduced by Friedrich Schiller (1794).

Research on GBL has been a fast emerging and hyped field in the 21st century with a creation of various subfields. GBL is today an integrated part of various educational concepts and there are at least four different branches:

1. GBL by playing tailor-made educational games (Ljungkvist, Mozelius, 2012)
2. GBL by playing commercial of-the-shelf (COTS) games (Wiklund, Mozelius, 2013)
3. GBL to support social inclusion of disadvantaged groups (Bleumers et al., 2013)
4. Learning to program by GBL and game construction (Mozelius et al., 2013)

This study is based on the fourth approach combined with constructionism and the concept of multimodality.

### 2.2 Multimodality

Multimodality is about involving and using several modes concurrently in presentations and communication where a mode can be defined as a channel of communication that a culture recognizes (Kress, 2009). Within multimodality, media/interface could be books, computers, radio and TV and examples of sign systems are words, images, colours, and sounds (Allwood, 2008). The idea of multimodality has got an increased attention in the new technology enhanced Internet environments where people are able to use multiple modes in their every-day interactions with each other (Kress, 2009). In traditional education and pedagogy Bloom’s taxonomy (1965) has provided a hierarchy of cognitive-learning levels ranging from the basic root learning level to more advanced levels of analysis, synthesis, and creating. In Figure 1 below a more internet enhanced and multimodal taxonomy is depicted.
There are also studies on how interactive multimodal learning environments should they be designed to support students' learning. Moreno and Mayer (2007) identified five crucial design principles: guided activity, reflection, feedback, control, and pre-training. In GBL the multimodal principal is one of James Paul Gee’s 36 learning principles where Gee (2014) describes multimodality as a way to transfer meaning and knowledge in various modalities such as images, sounds, interactions and abstract design not just by words.

2.3 Constructivism

With the constructivist approach learning is a process of active construction rather than the view of learning as a passive transmission of knowledge. New knowledge is constructed by the learners through an active process based on their previous knowledge and in this process, earlier acquired knowledge is evaluated whether it is contrary or aligned to the knowledge being taught (Hadjerrouit, 1999).

The emergence of the constructivist movement was largely a reaction to the problems in education regarding the overstated emphasis on rote learning and algorithmic performance as the core procedures of education. It was observed that “saying the words of a principle does not produce understanding of what those words mean” which led to the constructivist perspective and seeing education as providers of opportunities for students to develop their own personal knowledge, by making appropriate learning situations available (Gott, Lesgold, Kane, 1996).

Consequently, constructivism is about creating understanding from learners’ perceptions and experiences (McMahon, 1997) and meaningful learning is to actively create structures of knowledge based on the earlier acquired experiences. The learner is then, according to the constructivist theory, forming a personal view of the world based on existing knowledge,
attitudes, interests and goals. In addition, Constructivist learning involves selecting relevant information and to interpret it (with the help of existing knowledge) to construct understanding and the teacher is seen as a participant to help developing skills to construct useful knowledge in that process. According to Mayer (1988), meaningful learning is then taking place when the learner selects relevant information and organizes the information into a coherent whole and integrates it with existing knowledge. This learning process can be summarized in three words: selection, organization and integration (Mayer, 1998).

2.4 Constructionism

Constructionism is a theory of learning that is based upon constructivism and shares the belief that learning is a process of “building knowledge structures through progressive internalisation of actions” but adds to that idea that “this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe”. (Papert, 1980)

This theory is student-centered and the emphasis is on discovery learning where students are supported to work with tangible objects and use prior knowledge to gain further knowledge. The purpose is to visualize the process of learning and thinking and to engage students in a more process-oriented way through construction and deconstruction. Teachers are not giving lectures or instructions step-by-step, but instead they are in the background taking the role as facilitators of students’ learning. Learning is achieved by tinkering with or constructing an entity or an object, where construction is looked upon as an activity of back and forth and with design as a part of the construction process, rather than a pre-requisite. (Alimisis, Kynigos, 2009)

Problem-based learning is a constructionist method where students are supposed to learn about a subject by exposing them to multiple and increasingly complex problems and require them to construct their understanding of the subject through the given problems. Seymour Papert has a vision that math students should live and construct their knowledge in Mathland (Cole, 2014) like students learn French by living in France. One design idea with the described course is that course participants should spend a summer in Gameland constructing their programming skills and knowledge by game construction.

3. Method

The study was conducted as a case study with the course that is described under Multimedia programming in Python as the studied case where data has been collected. This course was designed and implemented by the two authors at a department of computer science. In the summer of 2016 the course is given for the seventh time and the study is based on the first six versions of the course with course batches from 80 up to 400 students.

A case study case can be described as an investigation of a real world phenomenon (Yin, 1989) such as an activity or a process explored more in depth with data collected by various methods (Creswell, 2009). Case studies should also focus on one, or a few instances of the selected phenomenon with the aim of an in-depth description of activities and processes in the particular
instance(s) (Denscombe, 2003).
In this study data was collected from a literature review, course documents, evaluation questionnaires, and discussion fora in the course platform. Furthermore, there have been analyses of students’ submitted solutions to the course assignments and the mini-project where all course participants design and implement a digital game in the Python programming language.

3.1 RESEARCH ETHICS
No names or other personal details about course participants have been published and including the evaluation questionnaires that all have been kept completely anonymous.

4. MULTIMEDIA PROGRAMMING IN PYTHON

The course is an introductory programming course with the dual aim to teach Python and to attract new groups university programs at a department for computer and systems sciences. With the entire course syllabus is built around the idea that multimedia and game construction can stimulate creativity and active learning all course content is overloaded multimodal model in the online learning platform Moodle. All course content including learning lectures, tutorials and the course book are built around analysis and synthesis of digital games and provided in a classroom that was flipped before the term flipped classroom became trendy. Students have access to all course content and assignments from the first course day and during the rest of their lives.

Practically all assignments and the final mini-project are also built around the idea of learning by game construction. In the final project should implement a own designed digital game with a built-in tutorial and a demo video explaining gameplay and game mechanics For the first course batches students were free to build just any game if the game idea was complex enough to fulfill the grading criteria. Later students were required to construct an educational game and during the last years an educational game with a given topic for the learning outcomes. Examples of learning game topics have been IT-security, Mathematics and a chosen natural language. Course batches have consisted of groups between 80-400 students with ac setup where all activities can be completed in distance mode. Participants have been geographically spread with students from all over the nation and also with large variations in the age group. The youngest participants have been younger than 20 years and the oldest 65 years old. With a 50% study pace the course is given as a summer course from early June to late August.

Finally, multimodality and GBL are not only components for didactics and instructional design, they are also important parts of students solutions to the course assignments. As an example students record demonstration videos for their games and sometimes in their own Youtube channels. An appreciated complement that can shorten down the required textual work description of their game construction project.
5. Findings and Discussions

The combination of game construction and multimedia programming has worked fine for most participants in this rather diverse learner group. Course participants have been in all age groups from secondary school students to 65 year old engineers and they are spread geographically all over Sweden. The completion rate is higher for students above 30 years but some digital natives that started out early with programming have constructed games with excellent use of multimedia and exciting gameplay.

During the seven years that the course has been given it is only two participants that have been reluctant to the idea of constructing games. In the first course batches students were completely free to work with whatever game idea they found stimulating and assignments were more open-ended. This worked fine but lot of replicas of classic game ideas and some plagiarism issues. To copy existing game concepts can be a decent training in programming techniques but does not really foster creativity.

To get rid of plagiarism and to stimulate originality there is now always one or several given game themes where students have to build educational games. With students having large variations in pre-knowledge and backgrounds there are also large variations in the game implementations and their code quality. For the higher course grades originality in design details and usability are rewarded together with more technical programming aspects. Some students mostly want the official carrots (credits and study funding) and take the easy way out and finish off the final project with fulfilling only the minimal requirements for the lower grades.

In all course batches there have been a mix of students driven by extrinsic motivation and the ones driven by intrinsic motivation. Students in the latter group often spend a large part of the summer in Gameland, programming for programming's sake and building more sophisticated games than what is required for the highest grade. When assignments are too open-ended the quality and originality tend to go down but on the other hand and originality and creativity seem to be hampered when assignments are too close-ended.

There are many course components that should be updated to live up to the ambition of a multimodal Gameland, but the success story that remains this course has the highest pass rate ever among all summer courses on programming, and all distance courses on programming at the department. However, the pass rate tends to go down the years when the course batches are smaller and Gameland seem to decrease severely in communication when the inhabitants are relatively few.

6. Conclusion

Findings indicate that GBL combined with multimodality can be a catalyst for energy and motivation especially for students in the digital natives generation. But the completion rate in this course is rather higher for the relatively old students. Some participants have left the course because they do not find game construction to be a serious way of learning to code, but they are not more than around 1 % of the students that enter the course platform.

The constructionist approach with a combination of problem-based learning, game construction
and multimodality might also be a way to increase pass rates in programming courses at university level. Furthermore, a multimodal design of course content and course activities seems to be a promising concept not only in Gameland. However, the described combination of constructionism and multimodality is no silver bullet, and rather just one of many promising e-learning strategy worth considering.

7. Future Work

As mentioned earlier there is no need to further flip the classroom since all course resources and interaction channels are available 24/7 from the first day of the course. Authors would rather like to investigate the idea of an extended classroom where students should get start up activities and guidelines before the actual course start. This should be explored based on Moreno’s and Mayer’s (2007) design principles of: guided activity, reflection, feedback, control, and pre-training.
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