The 5/10 method: a method for designing educational games

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Abstract. Serious games may improve understanding, involvement, engagement, reasoning and inquiry, and have been successfully used in schools. Recent studies show that serious games are sometimes misused, and not always easy to integrate in an instructional environment. It is often unclear how a game contributes to student learning, or how it should be used in a course. This paper proposes a method to support the analysis, design, development, and use of serious games in education. The method combines the widely used design model ADDIE with the instructional design method '10 steps to complex learning'. The method is applied in the development of the Moth game, which supports learning optics at the level of high school physics.

Keywords: Serious games, design methods, instructional design, games for physics

1 Introduction

The game River City has been used since 2007 in a game-enhanced science curriculum to teach science to over 8000 students [6]. River City increases the self-efficacy of students and improves student learning. Combining video games and more traditional curricular materials improves the accessibility of the content, and learning is made more relevant to students [10]. A game like River City engages students, which is one of the advantages of using games in education. Autonomy in playing games allows a student to customize gameplay to their personal and cultural norms in a controlled learning environment [2]. A student can disassociate from personal perception of their physical appearance or ability levels, which supports students with low self-esteem or self-efficacy [1]. Using the game Whyville, Kafai et al. [5] show that the gameplay encourages students' participation in scientific arguments and leads to using higher-level vocabulary words. Other research shows that various categories of scientific games support and improve scientific discourse, reasoning and inquiry [1, 18, 7, 19]. More importantly, students from all groups and ages report that they prefer to learn science from a game rather than from a traditional text, laboratory-based education, or internet environments [11].

The learning effects of serious games in studies across educational contexts [21] are inconclusive. One of the recommendations is to ensure that game objectives and learning objectives correspond. It is often hard to determine whether or not a game contributes to a student's learning because of a lack of clearly defined learning objectives and outcomes [9]. Furthermore, even though games can be a very powerful educational tool, there is often an integration problem in the instructional environment.

There exist several models that support the design of serious games [4, 12, 8]. The focus of most of these models is on how to design the gameplay of serious games. In this paper we focus on how to integrate a serious game with the existing curriculum. We propose the 5/10 method: a method that provides guidelines for the design of a game with clearly defined learning goals and objectives, and with a connection to the existing curriculum. The method is a combination of the general design method ADDIE, also used in DODDEL [12], with the instructional design method developed by Merriënboer and Kirschner [14]. We think our method is complementary to existing design methods, and can help to design a game that integrates well in the existing learning environment.

2 The 5/10 Method

This section first briefly describes the ADDIE method and Merriënboer and Kirschner's 'Ten steps to complex learning', and then shows how these two approaches are combined to obtain the 5/10 method for educational game design. The 5/10 method focuses on the instructional system design and largely ignores the design of the artistic components of a game, such as visual, audio and specific level design. While these components are very important for game design, their design is a separate field of research and out of scope for this paper.

2.1 The ADDIE method

ADDIE (Analysis, Design, Development, Implementation and Evaluation) [16, 20] is a widely used method in product design and especially in instructional system development, such as teaching methods, books and educative games. The ADDIE method provides a good basic skeleton to create an educational method [3]. We use ADDIE as a global framework for the more fine-grained design method using the Ten Steps to Complex Learning [14], which we describe in the next subsection. In the design phase of ADDIE many of the ten steps are used to ensure that a game is designed based on clear learning goals, and that it provides a player with the right information at the right time.

2.2 Ten Steps to Complex Learning

The ten steps to complex learning constitute a holistic method for designing instruction. The method does not separate a complex domain into unrelated pieces, but approaches the problem of learning in a particular domain via simplifying complex tasks in such a way that a learner is confronted with whole, meaningful tasks from the start. The ten steps to complex learning are based on Merriënboer's 4C/ID method [13]. The 4C/ID approach describes blueprints for complex learning by means of four basic components: learning tasks, supportive information, procedural information and part-task practice. Learning tasks include a case that has to be studied, a project that has to be done, a problem that needs to be solved and so on. Supportive information is information necessary to perform non-routine tasks such as problem solving and reasoning. Procedural information is information necessary to perform those parts of a task that are always performed in a similar way. Finally, part-task practice is needed if a learner needs to achieve a very high level of automaticity in part of the task. The blueprint components are developed and designed in ten steps. Of these ten steps, four are design steps, and the other six support these design steps, and are only performed when necessary. The ten steps are:

1. Design learning tasks
2. Sequence task classes
3. Set performance objectives
4. Design supportive information
5. Analyze cognitive strategies
6. Analyze mental models
7. Design procedural information
8. Analyze cognitive rules
9. Analyze prerequisite knowledge
10. Design part-task practice

The ten steps method follows a so-called pebble-in-the-pond model [15], in which the learning tasks represent a pebble thrown in a pond. Each of the subsequent steps grows from that first step like ripples in the water, adding more and more until a full task emerges.

2.3 The 5/10 method

The 5/10 method combines the ADDIE method with ten steps to complex learning to obtain a method for designing educational games. The design process described in the method is depicted in Figure 1.

We have used the steps of the 5/10 method in the design of Moth, a serious game for learning optics at the level of high school physics, see Figure 2. The goal of Moth is to practice optics in the final year of the VWO (Preparatory Scientific Education) level of high school in the Netherlands. We do not have space to describe how we applied the method in detail, but give some of the steps below. Please refer to the MSc. thesis of Van Rooij [17] for further details.

Analyze: The first step consists of four sub steps to determine global learning goals, to analyze the learning material and background, to analyze existing teaching methods, and to analyze related educational games. The learning goals

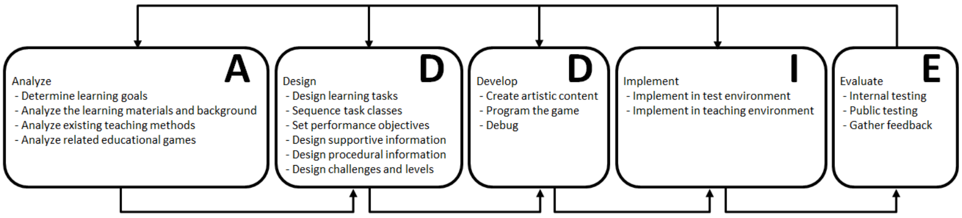

Fig. 1. The 5/10 method

Fig. 2. The interface of the Moth game

for optics are described in a national standard. There are six learning goals, examples of which are: to know and to use Refractive Index and Snellius Law, and to know and to use the lens formula, including being able to calculate and use focus points, lens strength and construction rays for a positive lens.

Design: Now we are ready to start with the design phase of the 5/10 method. In the design phase we design learning tasks, sequence task classes, set performance objectives, design supportive information, design procedural information, and design challenges and levels. These steps correspond to a large extent to the ten steps to complex learning. Some of the ten steps to complex learning are missing here, namely analyze cognitive strategies, analyze mental models, analyze cognitive rules, and analyze prerequisite knowledge. These are the steps supporting designing supportive and procedural information. In almost all cases supportive and procedural information is present in the teaching methods and learning material analyzed in the analysis phase of the 5/10 method. The four omitted analyses have been performed by the developers and authors of the teaching methods and learning material.

To design learning tasks, we look at the learning goals again. It is relatively straightforward to translate the learning goals to learning tasks. For example, for the learning goal: to know and to use Refractive Index and Snellius Law, we directly obtain the learning task: calculate the refractive index, angle of incidence or angle of refraction using Snellius Law.

In the second design step we have to sequence task classes. To sequence task classes we should take the difficulty of a task and the amount of support provided into consideration. Merriënboer and Kirschner [13] advocate a cyclic development of increasingly complex tasks, with decreasing amount of support. Furthermore, often the existing teaching methods and learning material offers tasks in a particular order. The order we present is the order used in the Dutch Newton teaching method, and advised by the high school teacher we interviewed: 1: Law of reflection, 2: Formula of magnification, 3: Lens formula/focus, 4: Snellius Law and refraction, including different wavelengths. We use this order to sequence the levels in our game.

Develop: In the development phase we design the artistic contents, program the game, and debug the result. Moth has been implemented in GameMaker 8.1.

Implement: In the implementation phase, the game is first deployed in a test environment, and then in the intended teaching environment. The game is released on the website `https://sites.google.com/site/yarentertainment/`. The game has also been installed on the machines of a high school in Zeist (The Netherlands), at which we performed an evaluation of the game.

Evaluate: Moth was played by both high-school students and university students, 12 of whom filled out a questionnaire. Van Rooij [17] gives a detailed description of the results of the questionnaire. On the positive side, players were very motivated to finish the game (8.7/10), and thought the game helped them practicing the material (8.8/10). The difference in difficulty between some levels is far too big (4.3/10), and the user interface needs to be improved (5.1/10).

3 Conclusions

We have developed the 5/10 method: a method for analysing, designing, developing, implementing and evaluating serious games. The method helps collecting the data necessary to design an educational game, and the information a student needs while playing the game. The method combines the ADDIE method and the ten steps to complex learning for the instructional design of serious games. We have developed the game Moth using the method. Moth was designed and developed in a couple of months, and although the evaluations show that it can be improved, much has been achieved in a short period of time.

Acknowledgements: Anastasia Stebakova designed the environments and characters of Moth. Kevin MacLeod (incompetech.com) composed the music of Moth. Anton Bondarenko created an introductory and a concluding movie for Moth.

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