Great Adventures for the Millennium chemical Engineering Student
GAMES

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INTRODUCTION

Chemistry is often perceived as a difficult branch of science in educational institutes. In both secondary education and higher education programs, students have been known to struggle with the usually more abstract matter. At the engineering department of the KU Leuven (BE), these struggles have already been noted for a long time. In the bachelor program, all engineering students take the course General and Technical Chemistry (GTC). This course treats the subject of basic chemical concepts, which are an essential part of the broad knowledge of an engineer. The scores of the students for this course are undeniable: every year almost half of the students fail the course.

The goal of the GAMES project is to improve the understanding of the engineering students of some of these abstract chemical concepts via a game-based learning approach. This will hopefully result in a better understanding of chemistry and a greater motivation to learn more. It will be investigated whether the game has a direct effect on the students' grades for the GTC course and whether it indirectly impacts their performance as it influences their learning attitude, self-efficacy (regarding chemistry) or academic motivation.

1 GAMES: GOALS AND ORGANISATION

1.1 Goals

The goal of the GAMES project is to increase the engineering students' understanding of some chemical concepts, which are essential for the education of a chemical engineer. Over the last decades, and especially in the last few years, the landscape of (higher) education has completely changed. With the introduction of the Internet, online encyclopedia, online teaching platforms, adaptive software, applets and, more recently, smartphones and tablets, the way the students nowadays experience (higher) education differs immensely from before.

Notwithstanding these major changes, a lot of the courses of the engineering education at universities, including the GTC course at the KU Leuven, have barely changed: not in content and not in their design. This is the reason why the GAMES project, which stands for "Great Adventures for the Millennium chemical Engineering Student", tries to implement new ways of teaching that better fit the modern profile of an engineering student.

Since the millennium student spends less time reading (in books) and more time playing, surfing on the web and reading on the computer, the GAMES project will use the computer as a teaching medium and introduce digital game-based learning in the engineering formation to investigate how it can complement existing learning methods. Game theory has exposed that game play is characterized by such elements as meta-cognition, ongoing learning and gradual learning [1] [2]. However, empirical research has not yet provided conclusive results regarding the conditions under which successful DGBL occurs [3].

The project, which will take two years, will deliver a functional prototype of a computer game as well as a full game concept, aiming to increase the understanding of some of the basic chemical concepts from the GTC course: Lewis structures, the VSEPR model, the Le Châtelier-Braun principle and some general reaction types. The possibility to expand the content of the game in order to include more advanced chemical concepts will also be investigated during the course of the project. The

expanded game could be used as a tool throughout the entire chemical engineering formation.

1.2 Organisation

The GAMES project is a collaboration between four different departments: the Department of Chemical Engineering (KU Leuven), the Play&Game Research Group (KHLim), the Teaching and Learning Department (KU Leuven) and the Centre for Instructional Psychology & Technology (KU Leuven).

The Department of Chemical Engineering is responsible for the input of the chemical concepts of the game and its introduction in the engineering formation. The Play&Game Research Group is the (main) creative cell and is responsible for the scenario, screenplay and development of the game. The Teaching and Learning Department translates the pedagogical goals of the course into a game-based learning format. The CIP&T takes an advisory role and also keeps track of the implementation of appropriate pedagogical methods.

In order to keep a good contact with the target group, two panels have been formed: the Focus Groups (FG) consisting of a number of bachelor students and the Sounding Board Group (SBG) consisting of bachelor, master and PhD students in the chemical engineering programme. The FG gives input on dedicated issues during FG interviews. The SBG can give feed-back on strategic decisions during the project.

2 APPROACH

2.1 Survey of the target group

To determine what type of game would be developed, an explorative investigation of the target group's gaming motivations and preferences was performed. During FG interviews, the following research questions were addressed: Which genres and game mechanics do they prefer? Which are their main motivations to play? How do these result in specific playing practices? It was also recorded how frequently the participants play computer games and during which moments/periods their gaming behaviour is more/less intensive. A brief summary of the main results of the FG interviews can be found in *Table 1*.

Four possible game types were considered for the GAMES project: an adventure game, a strategy game, a god game[4] and a shooter. For each type a proof of concept was elaborated, which was subjected to a comparative expert analysis. As a result the four options were narrowed down to two: the adventure game and the god game. The adventure and shooter games on the one hand and the god and strategy games on the other are very similar (to play and to program). Programming all four games would take too much time. Once one game is (partially) developed, conclusions about the similar game can be drawn as well. Also, the shooter game was considered to be less suitable to convey the chemical concepts, because of the limited player actions.

[4] A god game is an artificial life game that casts the player in the position of controlling the game on a large scale, as an entity with divine or supernatural powers, as a great leader, or with no specified character, and places them in charge of a game setting containing autonomous characters to guard and influence.

Table 1. Results of the FG sessions (3 groups)

Gender differences?	Female students	Limited gaming; easy games
	Male students	More intensive gaming
Genre preference?	Non-gamers	Short, easy games; games that you can play with others ("social games")
	Gamers	No real preference
Console preference?	Non-gamers	Mobile phones, tablets, Wii
	Gamers	Depends on type of game but no general preference
Time spent?	Non-gamers	Not much: in between courses, on bus, etc.
	Gamers	More, but less than in high school
Social aspect?	Non-gamers	Definitely an asset
	Gamers	Depends on type, but often an asset for a game
Do / don't?	Do	Good graphics, good storyline and build-up, humour, competition
	Don't	Too much text, completely realistic graphics and scenery (impossible to succeed completely)

2.2 Scenario of both game types

For both game types, the god game and the adventure game, a rough scenario and a first graphic design were developed.

In the god game the player has to transform a barren planet into a viable ecosystem. The player uses robots to explore the planet, gather resources and construct buildings. Most resources are minerals similar to those that can be found on Earth. However, some take the form of molecules that cannot be found under atmospheric conditions like, for example, hydrogen gas. The player can use these resources in a laboratory, and split the molecules into atoms, which can be recombined to create new molecules. Once these new molecules have been examined, the player has to build more advanced industrial installations to start producing them on a larger scale. The goal of the game is to effectuate the right atmospheric conditions on the planet, in order for a desired type of creatures (humans, intelligent alien bugs, ...) to populate the planet.

In the adventure game, the player is trapped in a labyrinth (the remains of an old temple or factory), and the goal is to escape. In order to reach the exit, the player must solve a number of puzzles based on the chemical concepts of the GTC course. While advancing through the game, the player finds a range of tools that are linked to the mystic art of alchemy. An example of such a tool can be a set of 'magic gloves' that can be used to heat up objects.

2.3 Final choice of the game type

To select the game type, the SBG was involved. The question for the SBG was to analyse both games in terms of game play and implementation of the GTC course and decide which one they liked more. The SBG reached the same conclusion as the project team: the adventure game allows for a better implementation of the chemical concepts from the GTC course and will probably have a greater success amongst the non-gamer students. Some of the main arguments can be found in *Table 2*.

Table 2. Comparison of the adventure game and god game

	Adventure game	God game
Advantages	- Clear storyline - Clear link with the GTC course - Gradual build-up of complexity - Less freedom (non gamers), more control	- Good distinction between the macroscopic world and the microscopic laboratory - Social aspect possible - Gradual build-up of complexity - Freedom, creativity (gamers)
Disadvantages	- No replay of the game: always the same scenario and puzzles - Less freedom - More programming: each puzzle needs to be programmed	- Huge database required from the start - Game does not fit the content of the GTC course (no organic chemistry) - Freedom, creativity (non-gamers)

3 DEVELOPMENT OF THE GAME

3.1 Storyline adventure game

In the story, the player is trapped in an old and seemingly abandoned laboratory. A century earlier, a crazy and power-hungry Dmitri Mendeleev had been trapped in the same laboratory by his colleague scientists, who feared the powers of alchemy that Mendeleev had been experimenting with. In the beginning of the game, the player unwittingly frees Mendeleev, who has managed to stay alive all those years, thanks to his experiments with the darker side of alchemy. The player needs to find the exit before Mendeleev does and prevent him from escaping the ruins.

3.2 Introducing the chemistry

As mentioned before, the player has to solve puzzles to advance through the ruins of the laboratory. These puzzles are based on the concepts from the GTC course, and take on different forms, depending on the player's progress in the game world. Some puzzles are placed in the inventory backpack of the player, and need to be solved to create the right molecules. Other puzzles influence the state of elements in the game world, because solving them may for example cause a chemical reaction or influence certain molecules using the Le Chatelier-Brown principle.

As soon as the basic structure of the game world has been created, students will be invited to participate in another FG meeting, wherein further details of the game will be elaborated by means of collaborative design methods. The same procedure will be applied in several iterations, using sample prototypes of puzzles and actions in the game world. In the last phase, the final game will be programmed, designed and tested by students of the course.

3.3 Pedagogical alignment

The primary goal of the game is to facilitate students' learning of certain chemical concepts. Students will be able to realise some of the learning goals of the GTC course through gaming. In order to do that, during the development of the game, there is an explicit focus on how some chemical concepts will be learned or practiced through gaming. All essential steps to understand but also apply these different chemical concepts (in real life or assessment environments) were first dissected. This analysis was a crucial step to see in which way the chemical concepts should be integrated into the game. The concepts should be operationalised in the game in such a way that they mimic thinking about and working with them in real life. Additionally, the order in which students will be confronted with the different concepts is important because certain concepts are hierarchically related or because the order of appearance would be the same between the game and all course modules involved. By designing the game in this way, it will be developed as a learning material for the GTC course. Logically, some learning goals will be reached through the game, but the integration of the game in the rest of the course will also be part of the redesign of the complete course.

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