Science4Exitschool: Escape Games for Chemistry Classes

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Abstract: Chemistry can often be very abstract. For this reason, different learning environments and methods are increasingly being developed to make it more accessible to learners at school or university. One such method is the use of educational escape games (Avargil, Shwartz and Zemel, 2021). This term refers to live-action, team-based games. In these escape games, clues must be followed, puzzles and tasks must be solved within a certain time frame in order to reach a certain goal (Tercanli, Martina and Ferreira Dias, 2021). This concept offers new opportunities for the educational sector. Learning pedagogy categorises this as game-based learning. The game serves as a medium for learning and achieving specific learning goals (Hu *et al.*, 2022). Entertainment is not the main focus, but should be used in a targeted way to convey knowledge or elicit certain behaviours (Sailer, 2016). Through experimental escape games with digital enrichment, previously acquired knowledge can also be applied and consolidated. As not only the popularity of the subjects of chemistry and physics has declined, but also scientific competences (Dohrmann, 2019), it is particularly relevant for the STEM field to introduce students to these topics in a playful way (Veldkamp *et al.*, 2020) and thus increase their interest in dealing with scientific topics. Escape games have already been shown to promote teamwork, problem-solving skills and creativity (Hacke, Przybylla and Schwill, 2019). These skills are part of the 21st century skills. In the context of the Science4Exit$_{school}$ project, this concept will be applied to the teaching of chemistry in schools. In addition to the technical background, the paper will also describe how this innovation can be implemented as an example.

Keywords: Escape games, Gamification, Chemistry classes, learning

1. Theoretical Context

Gamification refers to the application of game content and mechanics to educational or non-gaming contexts. Through the use of different processes and activities, a connection can be made between learning and game elements (Kim *et al.*, 2018). Gamification has been found to have positive effects on motivation, engagement, well-being, participation, interaction and collaboration among learners (Sailer, 2016). As society is constantly changing, the way we learn is also evolving. Due to its attractive and motivating nature, playful content is increasingly being implemented in learning contexts, especially in schools. Play is an intrinsically motivated activity for children and young people that helps them to solve problems, interact with others and their environment, and acquire realistic skills (Oerter, 2007).

With the rapid development of digital and social media, there is a great opportunity to expand gamification into the field of knowledge transfer (Jacob and Teuteberg, 2017). When a game is used with a specific learning objective in mind, it is referred to as game-based learning (Tercanli, Martina and Ferreira Dias, 2021). One method of game-based learning is educational escape rooms, which are becoming increasingly popular in providing learners with a new learning and assessment environment (Fotaris and Mastoras, 2022). Educational escape rooms are live-action games in which players, usually in teams, solve puzzles and tasks and follow clues, with a focus on teaching learning content or applying previously learned knowledge. The primary goal is to escape from a room, and the games can be embedded in different themes that lead to different missions (Veldkamp *et al.*, 2020).

However, due to safety concerns in chemistry, it is not possible to lock students in a laboratory. Therefore, there is a variation of this method, known as escape games, which can exist virtually or in the imagination. In these games, various locked objects are integrated in addition to puzzles and tasks (Dietrich, 2018). Escape games can be played flexibly in the classroom, online, with a box or as a board game (Menon, Romero and Viéville, 2019). In the educational context, puzzles and problems can be based on a technical challenge and thus on an operationalisable learning objective (Strippel, Philipp Schröder and Sommer, 2022). In the field of chemistry, these are chemical professional competences such as experimentation, scientific literacy, etc.

1.1 Escape Games

An escape game can be structured in a number of ways, with six key elements at its core. The game needs a *narrative*, which involves giving the game a compelling story. To coordinate the different stages of the game, you need to consider the *game-flow*, which gives the game its structure. Two other elements are needed during gameplay: *puzzles* and *equipment*. Puzzles represent the various tasks and puzzles that require both

physical and cognitive skills and can vary in difficulty. The design of the game can be implemented using equipment, which can be digital or physical. The category of educational escape games includes two other essential elements: *learning* and *debriefing*. Learning involves the delivery of curricular and extracurricular content and the development of specific competencies. Debriefing refers to the post-game process that completes the learning phase. This can ensure sustainable knowledge acquisition (Remmele *et al.*, 2020).

2. The Project Science4Exit$_{SCHOOL}$

Under the title "Science4Exit School", a PhD project is developing, testing and evaluating, using quantitative questionnaires, various escape games for chemistry lessons from grade 7 onwards. The escape games are intended to provide a motivating framework for students to engage with the subject matter, deepen their understanding and achieve a transfer of learned knowledge through a game-based context. In addition to traditional puzzles, the escape games include chemical experiments and digital enrichments (e.g. subject-specific content). Students are guided through the game via a digital learning environment implemented by embedding the escape games in an application such as Actionbound, genially, H5P, etc. These learning environments also include digital enrichments, such as explanatory videos, which provide background information, additions or assistance to the chemistry content in a didactically reduced way to support the students.

An escape game might involve a fictional criminal case. Various chemical experiments are embedded in a storyline to help catch a criminal. The different investigation methods include determining the colour composition of different pens, visualising secret messages, and visualising and matching fingerprints. The colour composition can be determined by the students using paper chromatography to find out whether a letter was written with a particular pen or not. For this investigation, you need a piece of filter paper with a hole cut in the middle with scissors. Two different colour samples are then applied to each side of the hole. Another piece of filter paper, rolled into a small wick, is pushed through the hole in the filter paper. The filter paper is then placed on a petri dish of water with the wick in the water. The water diffuses along the wick, carrying with it the water-soluble parts of the dye mixture on the filter paper. Due to the different solubility in water and the different strength of adsorption of the individual colour components on the filter paper, the mixture is then separated into individual colour components. (Figure 1). As most colours are mixtures, the resulting images will vary depending on the manufacturer and composition. The results of the investigation serve as new clues in the game, bringing the players step by step closer to catching the culprit.

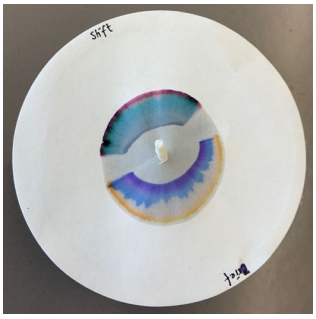

Figure 1: Result of a paper chromatography

In addition to experiments, classic puzzles, which can also be linked to chemistry content, are essential. For example, the periodic table and its structure lend themselves to integrated puzzles (Figure 2). The atomic numbers of each element can be used to generate numerical codes needed to break a combination encryption method (such as the Caesar cipher), which the students have to decipher.

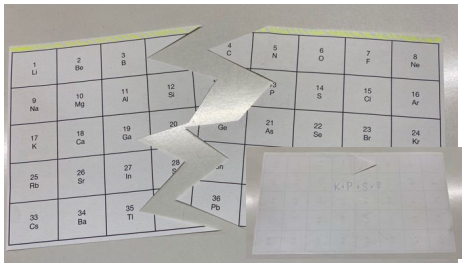

Figure 2: Periodic table puzzle (front and back side)

The developed escape games will be tested in schools, optimised and finally made available to schools as innovative teaching and learning materials. The escape games are designed in such a way that teachers can run them independently in their classes without the need for expensive equipment. This promotes equal opportunities regardless of the facilities or equipment of different schools.

The project is empirically supported and focuses on teacher and student motivation, feasibility and sustainable learning.

3. Prospects

This project will develop, test and evaluate additional escape games for use in schools on relevant topics in chemistry education. In cooperation with teachers, the method and its applications will be adapted and prepared according to the needs, so that the developed materials can be used in a variety of ways in the school context.

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