RESEARCH DIRECTIONS

# Digital Educational Escape Games in STEM Higher Education: A Systematic Literature Review

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## Abstract

In the post-pandemic era, lecturers in Higher Education (HE) are confronted with the challenge of motivational and attention deficits in their students. Hence, incentives to foster student engagement and motivation are subject to recent research. One such approach is game-based learning, involving specifically conceptualized games for HE, commonly referred to as serious games. One of these approaches is the digital educational escape games, a puzzle-based interactive game that fosters problem-solving abilities in a way of self-determined and constructivist learning.

Within the scope of this project, the current state of research regarding digital educational escape games for STEM (Science, Technology, Engineering and Mathematics), HE was investigated by conducting a systematic literature review.

Guided by the comprehensive Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, studies on digital educational escape games in the STEM disciplines were systematically selected. The studies were compared with regards to their methodology, focus and outcomes.

It was found that only few studies were conducted in the STEM disciplines. The primary areas of investigation in the studies are learner interaction, learner motivation and learning perception. Most participants perceive learning in digital educational escape games in a positive way and feel motivated by this learning method. Moreover, the studies serve as evidence for active student participation and engagement in learning material, when learning with a digital educational escape game. It needs to be stated that these findings are based on student self-perception assessed with questionnaires. Hence, a variety of methods applied in further research would enrich the state of research. Despite their positive effects, digital educational escape games in the STEM fields are not yet thoroughly investigated, resulting in the need of further research.

## Introduction

In the post-pandemic world, Generation Z is growing up in the times of digital transformation and mobile communication. Representing a third of the world population, Generation Z makes up for a

large share of HE students, contributing to societal change. The increasing use of digital media influences students' lifestyles and interests. This leads to a change in the way students learn, impacting their expectations from a study programme (Bencsik *et al.*, 2021).

Responding to this change, it is necessary for educators to initiate transformation of teaching and learning towards modern, incentivizing education (Becker *et al.*, 2021). Research focusses on digital media for educational purposes since generation Z mostly uses digital and virtual communication channels (Harari *et al.*, 2022).

Studies show that video games, especially those of competitive nature, are leading entertainment sources of young people around the world (Klöß & Erbach, 2023; Zhong *et al.*, 2024). As a result, a new branch of research has emerged. Game-based learning is a didactical concept that is based on actual games with the goal to achieve predefined learning targets. For educational purposes, games are often specifically designed based on specific learning objectives (Carvalho & Coelho, 2022; Zhang & Yu, 2022), therefore referred to as serious games (Weselek, 2022).

Serious games are an established tool in HE, allowing students to develop their competences in a safe environment. Students learn how their choices affect the environment while being able to make mistakes without serious consequences (Bencsik *et al.*, 2021).

An important serious game approach are digital educational escape games (DEEG). DEEG are digital games, in which students are virtually locked. In order to escape the locked environment, students need to enter key words. Hints to these are obtained by interacting with the locked learning environment, finding bits of information, which need to be assembled. This process fosters problem-based learning in an environment which allows learners to navigate autonomously and learn in their own pace. Students are required to actively interact with the learning material, resulting in higher engagement and participation (Wiemker *et al.*, 2015).

Due to the activating character of the game and the possibility for students to interact independently in the game, DEEG can be aligned with the self-determination theory by Deci and Ryan (1993). According to the aforementioned self-determination theory, students can be intrinsically motivated to learn if they experience competence development in an autonomous way, while still feeling a sense of belonging to their learning group (Deci & Ryan, 1993).

Furthermore, the features of DEEG point to a constructivist learning approach. Constructivist learning is based on the theory that students construct new knowledge. This process requires problem-solving competences, as learners independently engage with the learning material and are not guided by a teacher. Knowledge construction takes place based on interactions with and within the learning environment, or by means of interacting and discussing learning material with other people (Vygotsky *et al.*, 1980; Franco & DeLuca, 2019).

Considering these promising features, it is reasonable to conclude that DEEG have the potential to be an appropriate tool for HE. Especially the opportunity to develop students' problem-solving skills by learning in a DEEG can be expected to be a highly beneficial addition to HE. In particular, degree programmes in the field of STEM could benefit from this approach, as problem-solving represents an essential component of the scientific knowledge pathway (Makri *et al.*, 2021). Therefore, the objective of this study is to systematically investigate the state of research regarding DEEG in the STEM fields.

## Methodology

This paper is part of a comprehensive study on innovative teaching methods, with the intention to provide an overview of the subject area. Therefore, this study employs a systematic literature review (SLR), the latter being defined as identifying, evaluating and interpreting existing literature on a specific research question or fields of interest (Kitchenham, 2007). This systematic literature review is based PRISMA, serving as guidelines for reporting systematic literature reviews (Snyder, 2019). The latest reporting guidelines by Page et al. (2021) were applied for the identification of literature in databases, visualized in the following flow diagram.

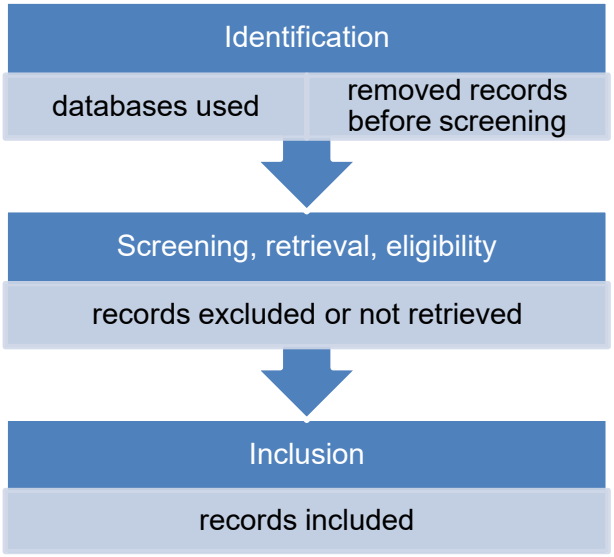


**Figure 1** SLR studies based on PRISMA guidelines (Source: Own elaboration based on Page et al. (2021))

**Figure 1** shows the process of conducting SLR based on the PRISMA guidelines in three main steps. The first step is to identify studies in the databases used. The second step serves as screening of these records, and, if accessible, the retrieval. In addition, studies are to be analysed for eligibility. The last step consists of the inclusion of the studies not excluded during the process. It is important to indicate the reason for removal of records in each step throughout the process.

## Results

The SLR was conducted with the cut-off date on November 11th, 2023. For validation purposes, the analysis was reconducted on December 16th, 2024. The databases used were ScienceDirect and the Karlsruhe Institute of Technology online library. The search comprised peer-reviewed literature, among others journal papers and conference papers, as well as dissertations. Due to unsuitable search results, the search was restricted to the keywords specified in the title. **Table 1** shows the search terms used.

**Table 1** Key words (Source: Own elaboration (2024))

| Aspect | Key word(s) |
|---|---|
| Digital escape game | Digital escape game OR digital exit game |
| Educational level | Higher education OR college OR university |

Based on the key words and the scope of the project, the exclusion criteria are the following:

- studies including games that are not in a digital format,
- research on games that do not follow the escape game logic,
- studies conducted in other educational settings than higher education,
- studies that were not accessible for retrieval,
- studies that are not peer-reviewed.

The findings of this selection process are outlined in the following figure.

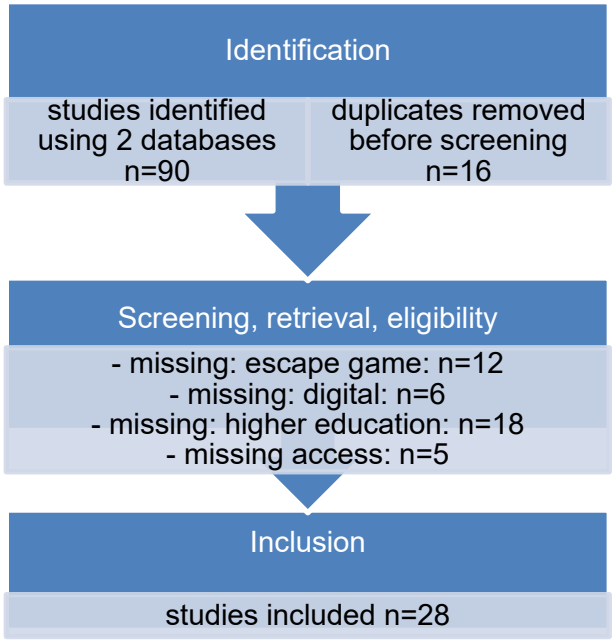


**Figure 1** General PRISMA flow diagram (Source: Own elaboration based on Page et al. (2021))

As visualized in **Figure 2**, 28 studies remain from the systematic process. The selected studies were published after 2019. Most studies were conducted in the fields of teaching (11) and healthcare (9). Conversely, DEEG have been the subject of limited research in the realms of business (3) and humanities (1), while only four studies were conducted in the STEM fields. The latter are investigated thoroughly in the following.

Accordingly, the four studies conducted in STEM disciplines are compared regarding their study focus. Studies on DEEG with participating students studying in the STEM fields were published after 2020. In the following, the studies are briefly described.

Wei Jie Ang et al. (2020) investigated a DEEG based on Google Forms regarding effects on motivation, perceived competence, utility and extrinsic incentives. The sample consisted of n=53 first year chemistry students in the academic year 2020. Students were divided into groups of four members for the intervention. A questionnaire using a four-point Likert scale was used to gather data. The authors disclosed no information on data analysis methodology. The analysis was focused on student motivation, including the variables interest/enjoyment, perceived competence, value/usefulness of the DEEG, relatedness as well as extrinsic motivation. It was found that the majority of students enjoyed the game and showed high values of relatedness. In general, the DEEG was perceived positively as an innovative approach and the participants feedbacked progress in


https://doi.org/10.29311/ndtns.vi20.4867

learning (Wei Jie Ang et al., 2020).

Monot et al. (2020) studied a web-based DEEG for chemical engineering students in the academic years 2017/2019. In total, n=117 participants took part in the study, working in groups of two to four students. The intervention was evaluated by a questionnaire in printed form with eleven questions based on a Likert scale. Data was analyzed using descriptive statistics, focusing on frequency distribution. The analysis was focused on usefulness, social interaction, learning perception and content of the game. With a response rate of 95%, all survey responses can be assigned high levels of agreement with a positive assessment of the DEEG. (Monnot et al., 2020).

Robrecht's (2023) study is primarily concerned with a DEEG based on WordPress, analysing the game functionality, knowledge acquisition and retention. The sample consisted of n=31 engineering students. Data was gathered by means of a questionnaire and analysed by summarising most important findings. It was found that participants were satisfied with the game. In general, students feedbacked a perceived knowledge development, while only one participant reported no knowledge gain. The author recommended that DEEG are suitable for the introduction of a new topic or the consolidation of a topic that the students are familiar with (Robrecht, 2023).

Van Wijk et al. (2024) created a web-based DEEG on water quality, assessed by n=30 science masters' students in groups of four in the academic year 2022. The data gathered in two questionnaires was analysed by a paired two-sample Fisher-Pitman permutation test with R to compare the distribution of perceived knowledge. Aspects analysed comprise a general opinion of the game as well as perceived learning. Significant differences were found between pre-test and post-test scores of perceives learning, with higher post-test scores. The authors recommended a pre-game instruction, presence of the moderator during the game and a debriefing after finalising the game (van Wijk et al., 2024).

In summary, the primary areas of investigation are learner interaction, learner motivation and learning perception. Most participants perceive learning in DEEG in a positive way and feel motivated by this learning method. The findings show active student participation and engagement in learning material. Furthermore, these findings are based on student self-perception assessed in questionnaires.

## Discussion

Following on from the findings of this SRL, several aspects need to be mentioned. To begin with, the four studies are based on self-perception questionnaires. Statements based on self-perception can distort the results if there is an underlying intention to act. Hence, it is recommended to apply a more distanced way of data gathering, for instance logfile data of the DEEG used or qualitative observations

Considering the research interest of the studies, the latter were mostly based on student interactions in the DEEG, not properly assessing the interactions. Therefore, including logfile data is expected to broaden the analysis by additional data. Moreover, it is recommended to enhance the analysis of learning outcomes by conducting knowledge tests prior and after the intervention, referring to the methodology used by van Wijk et al. (2024).

Another aspect is that only few studies exist on DEEG in STEM subjects. The latter include science as well as engineering, while mathematical and technological study programs are not mentioned. This leads to the first limitation of the state of research. Consequently, it is recommended to conduct further research of DEEG being applied in the mathematical and technological fields of higher education.

On the contrary, the non-STEM studies found in the SLR but excluded from the deeper analysis may enhance the discussion. These studies could provide further insights, their transferability to STEM contexts needing to be verified. For future research projects, it is also suggested that meta-analyses be carried out to establish a starting point as a basis for discussion and thus increase the comparability of the results.

In conclusion, the research carried out has shown the positive associations that students make with DEEG as an innovative learning method. Nevertheless, it can be stated that DEEG in the STEM fields are not yet thoroughly investigated, resulting in the need of further research. Moreover, a diversity of methods applied in further research would enrich the discussion and the state of research.

This SLR will be succeeded by an interview study to explore DEEG in STEM higher education through the medium of qualitative research. Subsequently to this investigation, a DEEG based on a STEM subject will be developed and subsequently evaluated in university teaching by the authors of this paper. The objective is to contribute to the field of DEEG in STEM university teaching, an area which to date has received little research attention.

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