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INVESTIGATING TEACHERS' PERSPECTIVES ON GAME-BASED LEARNING IN
GERMAN HIGHER EDUCATION IN STEM AND LIFE SCIENCES

Master's thesis

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Investigating Teachers' Perspectives on Game-based Learning in German Higher Education in STEM and Life Sciences

Abstract

Utilizing games and playful elements to enhance student learning has long been a practice in educational settings such as higher education. Although benefits and challenges of game-based learning are widely investigated, higher education teachers' perspectives on game-based learning in science, technology, engineering and mathematics (STEM) and life sciences are to date not much examined, especially in German higher education. The purpose of this thesis was therefore to investigate higher education teachers' perspectives on benefits and challenges of game-based learning in Germany using in-depth semi-structured interviews. Higher education teachers (n=7) who had previous experiences using or implementing game-based learning with university students were interviewed. Benefits of game-based learning for teachers (e. g. creating motivational environments) and students (e. g. safe-space for trial and error) as well as challenges for teachers (e. g. technical issues) and students (e. g. overwhelming situations) were identified from a teachers' point of view. The results of this thesis are in line with previous findings. They underline the opportunities of game-based learning in higher education also in connection with advancing immersive technologies such as virtual reality (VR).

Keywords: game-based learning, higher education, STEM and life sciences, benefits and challenges, teachers' perspective

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1. Introduction

Continuous youth surveys in Germany during the last years state that digital games became omnipresent elements in the daily life of young people since a huge overall majority of 12–19-year-olds play digital games (for example on computers, smartphones or tablets etc.) on a daily or weekly basis (mpfs, 2022). Since (digital) games are part of our daily life and especially relevant for young people, the idea of making use of games or playful elements in learning and teaching is not new to education, pedagogy or psychology and researched from different perspectives among all levels of education including higher education (Egenfeldt-Nielsen, 2006; Jan & Gaydos, 2016; R. E. Mayer, 2019; Shaffer et al., 2005). New (digital) technological advances shape the current generation of university students (Anastasiadis et al., 2018; Oblinger, 2004) therefore effects of game-based learning in higher education are mostly investigated in the light of benefits and challenges *for students* such as motivation, deeper learning and learning performance (Riopel et al., 2019). In contrast to that, the *teachers' perspective* on game-based learning in higher education is less investigated. Existing studies on higher education teachers' perspectives on benefits and challenges of game-based learning for teachers and students address teachers from different disciplines such as economics (Jääskä & Aaltonen, 2022) but comparable publicly available studies are missing to date in science, technology, engineering and mathematics (STEM) and life sciences, especially for higher education teachers in Germany.

Therefore, the purpose of this thesis is to investigate higher education teachers' perspectives on game-based learning in Germany in STEM and life sciences with a special focus on benefits, opportunities and challenges of game-based learning for teachers and students in higher education from a teachers' point of view. Thus, the aim is to provide an overview of current perceptions, observations and perspectives in order to understand specific obstacles and chances in these disciplines applying game-based learning approaches.

To proceed with the investigation, this thesis will first outline important theoretical foundations of game-based learning and then focus on higher education with a special focus on STEM subjects and life sciences. Following, a brief overview of research on benefits and challenges of game-based learning for students and teachers in higher education will be summarized. Consequently, the research questions and objectives will be outlined (chapter 2). Next, the methods and materials of this study will be described including sampling, data collection and methods of data analysis (chapter 3). The results of this thesis will then be presented (chapter 4) and critically discussed also regarding the limitations and the relevance of this study as well as possible follow-up questions in the light of the initial research questions (chapter 5).

2. Theoretical Overview

This chapter will focus on the theoretical overview of this thesis by first outlining definitions and theoretical foundations of game-based learning (chapter 2.1) also synthesizing the pedagogical and learning theory perspectives. A closer look will be taken on game-based learning in higher education including STEM and Life Sciences highlighting the benefits and challenges for students and teachers (chapter 2.2).

2.1 Game-Based Learning

To begin with, game based-learning can be understood as the use of games or game play which aim a defined learning goal, purpose or outcome (R. E. Mayer, 2014; Plass et al., 2015; Shaffer et al., 2005). In fact, game play for learning “is intended to cause (...) a change in the player’s knowledge or skill (...)” (R. E. Mayer, 2014, p. 4). While some studies focus on digital games and computer games (R. E. Mayer, 2014; Shaffer et al., 2005), this general understanding of game-based learning does not only apply to digital games but can be extended more generally also to non-digital games (Plass et al., 2015). In this context, digital or computer games for learning are defined as games for learning which are “delivered electronically” (Mayer, 2014, p. 4). Although the definition by Salen and Zimmerman (2003) which defines games as “a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome” (Salen & Zimmerman, 2003, p. 80) is frequently referred to, a common definition on “games” is rather vague and continuously discussed among scholars (Plass et al., 2019). Some authors therefore specify defining characteristics of games (Kapp, 2012; R. E. Mayer, 2014) in order to operationalize “games” for game-based learning. According to R. E. Mayer (2014), games can be summarized according to five characteristics: games are (1) following defined rules in a simulated or modelled system (R. E. Mayer, 2014), (2) responsive and interactive and therefore a player’s action will cause a reaction and response in the game (R. E. Mayer, 2014), (3) challenging by offering possibilities for the player to solve difficult tasks (R. E. Mayer, 2014), (4) accruing systems in which the player can progress in or from different levels (R. E. Mayer, 2014), (5) appealing and interesting for the player to get involved (R. E. Mayer, 2014). Coming from this basic characteristics, Jan and Gaydos (2016) also distinguish four categories of games for learning and educational settings in a broader sense: (a) motivational games which “engage students in the behavior of learning desirable content or information” (Jan & Gaydos 2016, p. 7) highlighting the fun and motivational aspects of game play, (b) drill and practice games which focus on practicing, repeating, accustoming and acquiring

learning contents (Jan & Gaydos, 2016), (c) content mastery games which “facilitate the mastery of information, facts, concepts, or canonical knowledge” (Jan & Gaydos 2016, p. 7) and (d) “21st Century Competency Games” (Jan & Gaydos, 2016, p. 7) to enhance competencies necessary for future generations such as problem-solving, collaboration or critical thinking.

2.1.1 Gamification and Serious Games

In the context of game-based learning, “gamification” and “serious games” gained popularity as terms for the use of games for educational purposes. Although the borders between these terms and the concept of game-based learning are blurry (Belova & Zowada, 2020), a closer look is necessary in order to show similarities but also to differentiate them.

On the one hand, the term “gamification” refers to the implementation of game-like elements in order to increase interest and motivation into a topic (Cózar-Gutiérrez & Sáez-López, 2016; Kapp, 2012). While game-based learning does not only assume the use of games for educational settings but especially emphasizes the connection between learning contents and game play and also includes the (re-)design of learning activities within or with the use of a game (Plass et al., 2015), gamification refers to a rather general use of game or game-like elements and features to enhance the learners interest and motivation to get involved with a topic, also in originally non-game based situations (Al-Azawi et al., 2016; Cózar-Gutiérrez & Sáez-López, 2016). Accordingly, Deterding, Dixon et al. (2011) proposed a definition of gamification defined as “*the use of game design elements in non-game contexts*” (Deterding, Dixon, et al., 2011, p. 10, italics in the original text). Gamification therefore constitutes the use of game elements in educational contexts “rather than full-fledged games” (Deterding, Sicart, et al., 2011, p. 2426).

On the other hand, “serious games” comprise an important part of the concept of game-based learning in education (Egenfeldt-Nielsen, 2006; Jarvin, 2015) and can be broadly defined as “games designed for a serious purpose other than pure entertainment” (Ma et al., 2011). (Digital) Serious games designed to convey skills and contents for a serious purpose rather than to “just” entertain became famous with regard to their use for educational purposes in several state, military, social or economic areas (Djaouti et al., 2011; Laamarti et al., 2014; Shaffer et al., 2005). Caserman et al. (2020) characterize serious games as (digital) games which consist of an essential balance between two parts: (a) the serious part which includes the characterizing (educational) goal of the game (such as learning objective or subject content etc.) (Caserman et al., 2020) and the (b) game part which constitutes the entertaining elements of the game (such as enjoyment, experience flow, immersive experience etc.) (Caserman et al., 2020).

2.1.2 Pedagogical Perspective

Despite the previously described mostly common understanding on of game-based learning and (educational) games, different approaches to game-based learning in pedagogical practices can be found in literature (Jan & Gaydos, 2016). A special focus for this thesis will therefore be set on (1) self-directed learning, (2) teachers' competencies and (3) the role of instruction.

(1) To begin with, *self-directed learning* is identified as an important skill necessary for the 21st century (Toh & Kirschner, 2020) and can be defined as “any increase in knowledge, skill, accomplishment, or personal development that an individual selects and brings about by his or her own effort” (Gibbons, 2002, p. 2). Toh and Kirschner (2020) discuss video games as suitable for self-directed learning because of their inherent features (for example as a safe space for trial and error) and identified several factors that promote self-directed learning with (video) games such as (a) learning analytics (learners can monitor and reconstruct their own actions and learning in games as a metacognitive tool) (Toh & Kirschner, 2020), (b) defamiliarization (bringing players into new and unknown situations in which a standard routine would not apply) (Toh & Kirschner, 2020) and (c) scaffolded learning (gradual and consecutive construction of knowledge) (Toh & Kirschner, 2020). (2) For the use of games in education, Nousiainen et al. (2018) identified several areas of *competencies for teachers* in primary and secondary schools using game-based pedagogy such as: (a) pedagogical area (reflective use of game-based approaches with evaluation and decision making in teaching and learning) (Nousiainen et al., 2018), (b) technological area (implementation of game-based approaches with technological competencies) (Nousiainen et al., 2018), (c) creative area (exploration and self-development of teachers using game-based approaches) (Nousiainen et al., 2018). (3) Finally, Bado (2022) presents a comprehensive meta-analysis of game-based pedagogy in different settings (higher education, secondary education, industry/training) in which *instructional activities* were identified to be important at all stages of game-play (pre-game, game, post-game) such as trainings, classroom management, assistance and reflection (“debriefing”) (Bado, 2022). This highlights the significance of teacher instruction in all phases of game-based learning during preparing, planning, conducting and reflecting the game activity with the students (Bado, 2022).

2.1.3 Learning Theory Perspective

In addition, four foundations of game-based learning are discussed in learning theory: behaviourism, cognitivism, constructivism as well as sociocultural aspects (Egenfeldt-Nielsen, 2006; Homer et al., 2019). Especially the constructivist foundation and motivational aspects of game-play will be summarized to underline game-based learning in learning theory for this thesis.

The *constructivist foundation* of game-based learning constitutes the individual interpretation and construction of knowledge which is not “externally” given into the students’ minds but the result of individual processing (Egenfeldt-Nielsen, 2006; Homer et al., 2019). (Video) Games contribute to this perspective notably by creating “microworlds” (Egenfeldt-Nielsen, 2006, p. 198) in which the players can interact with objects to develop “situated understandings” (Shaffer et al., 2005, p. 107).

The guiding motif of the learning theory perspective on game-based learning is *motivation*, so “the learner’s willingness to exert effort to learn” (R. E. Mayer, 2019, p. 534). A basic assumption of game play in educational contexts is that “players’ interactions with the game will motivate them and will foster cognitive processing of the game content” (Plass et al., 2015, p. 268). R. E. Mayer (2019) summarizes different theoretical explanations for the motivational aspects of games such as: (1) focusing on personal importance of the game play (R. E. Mayer, 2019), (2) perceiving oneself as competent when playing the game (R. E. Mayer, 2019), (3) feeling control over the task (R. E. Mayer, 2019) or (4) target-orientation (R. E. Mayer, 2019). In a nutshell, motivational aspects of games are focusing on the reasons why players want to play a game and underline “that games are able to engage and motivate players by providing experiences that they enjoy and want to continue” (Plass et al., 2015, p. 270). To sum up, the motivational function (game features and structures), the engagement of players (design, decisions, context and interaction) and adaptivity (personalized contents and engagement of the game with the situation of the learner such as previous knowledge or cognitive abilities) are commonly argued and discussed as foundations and motifs for the use of game-based learning which relate to the learning theory perspective (Plass et al., 2015).

2.2 Game-based Learning in Higher Education

As stated previously, games are used as a versatile medium to convey information and to enhance learning, not only in primary or secondary school, but also in higher education.

The current generation of students differs from previous generations in the light of new technological advances such as digital possibilities (Oblinger, 2004) and their (changed) expectations towards the use of digital elements in teaching and learning (Anastasiadis et al., 2018). In sum, this can be seen as a trigger for new (online) learning approaches and methods in higher education and consequently also for (digital) game-based learning (Brown et al., 2018). This trend is enhanced with new technological advances such as virtual reality or augmented reality which moreover offer (more) immersive and interactive learning environments, not only in higher education (Alper et al., 2021; Fabris et al., 2019; Udeozor et al., 2023). Nonetheless,

Brown et al. (2018) also emphasizes that (digital) game-based learning as a pedagogical teaching method alone is insufficient and rather unlikely to “replace traditional forms of instruction” (Brown et al., 2018, p. 2). I. Mayer et al. (2013) investigated correlations and determinants of game-based learning in higher education and their interconnection. They found, that fun and enjoyment aspects of game-based learning correlate with learning satisfaction which is in line with previously described findings and theories that fun/enjoyment are important for learning (I. Mayer et al., 2013). Nevertheless, I. Mayer et al. (2013) also state that “it remains difficult to establish whether the learning makes it fun, or the fun makes it meaningful” (I. Mayer et al., 2013, p. 98). Similar findings were reported by Crocco et al. (2016) who in general found that enjoyment is correlated with progress in deep learning (for game as well for non-game use in classes) and that games not only increase enjoyment but also reduce anxiety during the learning process (Crocco et al., 2016) although this study is limited due to methodological issues (no randomized and control study design) (Crocco et al., 2016).

As well as for higher education in general, game-based learning in science, technology, engineering and mathematics (STEM) and life sciences is also applied to meet with the current student generation expectations for a demanding and versatile learning environment (Oblinger, 2004; Priyaadharshini et al., 2020). The term *STEM* summarizes and synthesizes the disciplines science, technology, engineering and mathematics, while *life sciences* comprise disciplines investigating the processes and structures of life. Literature known examples for game-based learning in STEM and life sciences are for example the use of games to foster and enhance students programming or debugging skills in the field of informatics (Priyaadharshini et al., 2020) or applications of game-based learning in engineering (Callaghan et al., 2013; Ebner & Holzinger, 2007). For biotechnological higher education, Bonde et al. (2014) investigated gamified virtual laboratory simulations using the software “Labster”. Furthermore, Boeker et al. (2013) tested the use of a digital adventure-game in medical education (Boeker et al., 2013).

2.2.1 Benefits of Game-based Learning

To start with, the most discussed (positive) effect of game-based learning in higher education is the influence of games on *students'* motivation (de Freitas, 2018; Jääskä & Aaltonen, 2022). In this sense, de Freitas (2018) states in their systematic literature review on the effectiveness of game-based learning in general that “games do enhance student motivation, are engaging and can be associated with behavioural change” (de Freitas, 2018, p. 80). Additionally, Erhel and Jamet (2013) underline these effects of (digital) game-based learning in their study with students (18-26 years) from different universities in Rennes in France resulting in positive

effects on motivation and deep learning in connection with different types of instruction and regular feedback (Erhel & Jamet, 2013). Moreover, Ding et al. (2017) also offer insights into the effectiveness and preferences of game-based learning among finance students in higher education reporting higher effectiveness of and higher preference for game-based learning among the tested students in comparison with “traditional” learning methods (Ding et al., 2017). These effects are in line with investigations on game-based learning in STEM and life sciences. Divjak and Tomić (2011) reviewed different studies on the effects of game-based learning in learning mathematics including higher education and report positive effects of game-use in mathematics on motivation and achievement of learning goals (Divjak & Tomić, 2011). This is consistent with findings of Bonde et al. (2014) using the virtual lab software “Labster” in biotechnological higher education resulting in high levels of motivation and interest of the students in response to the game-use (Bonde et al., 2014). Game-use was perceived more interesting than conventional methods or exercises and improved students test-scores showing positive learning effects and outcomes (Bonde et al., 2014). These results are similar to findings of the control group study by Boeker et al. (2013) for medical higher education students in Germany who identified positive effects of game-based learning in comparison to conventional teaching methods for students resulting in better results of cognitive knowledge and (more) positive attitudes towards their learning experience (Boeker et al., 2013). These effects are consistent with the systematic investigation by Riopel et al. (2019) on serious games in natural sciences in (higher) education resulting in games being beneficial for gaining declarative and procedural knowledge “with equivalent instructional time, than more conventional instructional methods” (Riopel et al., 2019, p. 197). In contrast to that, Ebner and Holzinger (2007) showed in the field of engineering that game use leads to equal learning results in comparison to “traditional” instruction methods but resulted in higher motivation and reflective learning process (Ebner & Holzinger, 2007).

For the *teachers'* perspective, Jääskä and Aaltonen (2022) assume that all beneficial aspects of game-based learning for students can be considered beneficial for teachers as well since they contribute to a successful learning outcome (Jääskä & Aaltonen, 2022). Sánchez-Mena and Martí-Parreño (2017) were interested in main drivers of teachers in higher education to use gamification in their teaching practice with the help of a phenomenology approach. The authors identified four main drivers of gamification from an educators perspective, namely “attention-motivation, entertainment, interactivity and easiness to learn” (Sánchez-Mena & Martí-Parreño, 2017, p. 434). Benefits for teachers are described as game-based learning being an inspirational and motivational source for teachers, enhancing student engagement and influencing development of generic skills with versatile teaching methods (Jääskä and Aaltonen 2022).

2.2.2 Challenges of Game-based Learning

Despite the overall positive effects of game-based learning for *students* in higher education also in STEM subjects and life sciences, some studies emphasize shortfalls and challenges of educational game-use. For example, Boghian et al. (2019) identified disadvantages of game-based learning namely (a) limited time resources and time management (time consuming) (Boghian et al., 2019), (b) discouragement of students in case of failure (Boghian et al., 2019) or (c) possible challenges in assessing learning outcomes after game play (Boghian et al., 2019).

Moreover, *teachers* also highlight several challenges for students such as higher cognitive load and increased stress level when using games as well as the risk of frustration (Jääskä & Aaltonen, 2022). Interestingly, Jääskä and Aaltonen (2022) also found that teachers perceive playing games in educational settings also as a danger if “playing happens just by pressing buttons of the game without focus or concentration” (Jääskä & Aaltonen, 2022, p. 7) and therefore educational contextualization of the game play is necessary (Jääskä & Aaltonen, 2022). Main challenges for teachers were identified in extra work to prepare the use of educational games, problems in controlling and assessing learning as well as technical problems (Jääskä & Aaltonen, 2022). The investigation of Sánchez-Mena and Martí-Parreño (2017) resulted in mixed views on gamification by teachers in higher education mentioning a possible “risk for classroom atmosphere” (Sánchez-Mena & Martí-Parreño, 2017, p. 434). Furthermore, four main obstacles were identified which include “lack of resources, students’ apathy, subject fit, and classroom dynamics” (Sánchez-Mena & Martí-Parreño, 2017, p. 434). This is also in line with Brown et al. (2018) who state that resources (for example peer-reviewed articles) are a barrier in implementing (digital) game-based learning in higher education (Brown et al., 2018).

2.4 Research Question and Objectives

To sum up, the research on game-based learning in higher education investigates effects of game-based learning mainly in two directions: (a) beneficial and challenging effects for students and their learning outcomes in comparison to “conventional” teaching methods and (b) obstacles and opportunities for teachers when using game-based learning in their teaching practice. While the benefits of game-based learning in higher education in science-related subjects for students are well examined, the teachers’ perspective on the game use and on benefits and challenges of game-based learning is to date not widely investigated. Consequently, the investigation of this thesis follows the research questions (RQ):

RQ1: How do higher education teachers in STEM-subjects and life sciences in Germany use games for learning?

RQ2: What are the benefits of game-based learning in higher education in STEM-subjects and life sciences in Germany from a teachers' point of view for teachers and students?

RQ3: What are the challenges of game-based learning in higher education in STEM-subjects and life sciences in Germany from a teachers' point of view for teachers and students?

The investigation of this thesis will further pursue the following objectives:

(1) Teachers' perspective in higher education: By setting the focus on teachers in higher education, a current lack of data is addressed by specifically understanding the perspective of higher education teachers such as professors, academic or scientific staff on game-based learning in their institutions in Germany. Explicit data from German Higher Education is rare in this field. Therefore, the first objective is to gather more data with this study in order to understand the teachers' point of view using game-based learning.

(2) Identifying challenges and benefits: Furthermore, the second objective of this study is to identify challenges, opportunities and benefits of game-based learning in higher education in Germany from an teachers' point of view. While many studies investigate effects of game-based learning on students' learning performance, motivation or skills, the teachers' perspective in higher education on challenges and benefits of game-based learning in their teaching practice needs more investigation.

(3) STEM and life sciences: By addressing specifically the field of STEM and life sciences, this study aims to provide more data from teachers of these subjects to support a better understanding of challenges and benefits of game-based learning from a teachers' point of view in STEM and life sciences in higher education.

3. Materials and Methods

The following chapter will describe the materials and methods used in this thesis to investigate the research problem and research questions (see chapter 2.3). The research design of this thesis followed the concept previously described by Jääskä and Aaltonen (2022) and applied semi-structured in-depth interviews. Jääskä and Aaltonen (2022) interviewed 22 teachers of project management in higher education from different countries independent of their actual previous experience with game-based learning. In contrast to that, the study conducted in this thesis focused only on teachers in higher education in Germany from STEM subjects and life sciences who already have had previous experiences with the implementation and/or use of games for learning in their own actual teaching practice (see chapter 3.2).

3.1 Materials

During the investigations of this thesis, the following materials and software were used to collect and analyse data as presented in Table 1. Software was either provided by the University of Tartu or used as publicly available free software versions.

Table 1: Software used in this study.

Software	Description	Resources/Links
Zoom Version 5.17.11	Video conferencing tool which allows recordings of online meetings.	https://wiki.ut.ee/display/IT/Zoom
audapolis Version v0.3.0	Software for automated transcription of audio-to-text (with file-input). Running on local drive, not cloud- or AI-based.	https://github.com/bugbakery/audapolis
DeepL Web-browser application	Automated translation software which allows for the translation of input text, PDF, Word or PowerPoint files. Used for translation German > English	https://www.deepl.com/de/translator
MAXQDA Analytics Pro Version 24.3.0	Software for the computer-based analysis of qualitative data e. g. interviews including visualization tools for data analysis and conclusions.	https://www.maxqda.com/

3.2 Sample

To recruit teachers using game-based learning in higher education in STEM and life sciences in Germany, the participants were selected according to two criteria before conducting the interviews individually:

- (1) The participants are teachers in institutions of higher education in Germany in the field of STEM or life sciences.
- (2) The participants have experiences with games for learning (implementation and/or use) in their actual teaching practice in higher education with university students prior to the interview.

All interviewees were verified in advance if they match these criteria by checking their individual teaching curricula (also according to their personally provided information) and, if digital games were used, examining the utilized digital games or game-based elements before the interviews (if available).

Sampling of the participants took place (a) contacting different central departments of institutions for higher education responsible for consulting and supporting educators in implementing new teaching approaches (such as digital game-based learning) or project leaders of teaching innovation projects or asking regional higher education teaching networks for contacts for suitable interview participants or (b) personal networks and connections with teachers in higher education institutions. Furthermore, interviewees were also selected with the help of contacted teachers or interview participants redirecting to colleagues or recommended teachers suitable for this study. Thus, a preliminary sample consisting of thirteen higher education

teachers from STEM and life sciences from five higher education institutions in Germany were recruited through this sampling method as possible interview participants. After checking with the participant criteria, four teachers had to be excluded as participants: two had to be excluded because they did not use game-based learning for teaching university students but only for pupils (for example in school labs); one teacher was involved in the game development but not in the actual application with university students; one university teacher had to be excluded from the interviews because their used teaching method/application did not qualify as a game (as defined in chapter 2.1). Two other university teachers could not participate because of personal reasons. Consequently, the interviews were conducted with a total sample of $n = 7$ teachers from three different higher education institutions in Germany in the disciplines of STEM and life sciences. To ensure anonymity of the interview participants, universities and participants were coded with letters and numbers (Tab. 2). All interviewees participated voluntarily in this study and agreed to the anonymized processing of the data from the interviews for this thesis (see chapter 3.3).

Table 2: Participants of this interview study and their additional information.

Participant	University	Position	Discipline
1	A	Professor	Biology
2	A	Professor	Mathematics
3	B	Academic Member	Biology
4	B	Professor	Medicine
5	B	Scientific Staff	Medicine
6	B	Professor	Medicine
7	C	Professor	Chemistry

3.3 Data Collection

In order to investigate the presented research question (see chapter 2.3), this work used an approach of semi-structured qualitative in-depth interviews for data collection (DiCicco-Bloom & Crabtree, 2006). This approach was chosen in order to gain detailed information about higher education teachers' experiences and perspectives on game-based learning in STEM and life sciences in-depth (Boyce & Neale, 2006). The semi-structured interviews were conducted with a set of pre-determined open questions (see Appendix 1) allowing for possible additional follow-up questions arising from the dialogues or discussions with the interviewees (Adams & Cox, 2008; Boyce & Neale, 2006). The pre-determined questions were intended to start with general observations of the educators on game-based learning coming then to a more detailed view on their personal teaching experience. The questions were pre-structured in five blocks (see Appendix 1) to give a first guiding thread through the interviews for the interviewer and to

guide the analysis of this thesis. The questions were tested during a pilot interview with one participant of this study. After that, seven questions were deleted from the original question set and four questions were synthesized into two questions (each) without changing the meaning and the intention of the original questions because they were overlapping with other questions or contents. The resulting final question set is presented in Appendix 1. The pilot interview was therefore also included in the sample and is part of the data of this study. All interviews were introduced with the same introductory text which was presented to the interviewees in order to ensure the same starting conditions and information for all participants (see Appendix 2).

The interviewees were informed about the subject of the interview in advance (topic of the interview: teachers' perspective on game-based learning in higher education in STEM and life science subjects with focus on opportunities and challenges) but the interview questions were not sent to the selected teachers prior to the interviews. Furthermore, the teachers were not asked to particularly prepare for the interview questions and contents. Communication until the interviews was entirely accomplished via e-mail and participants had to fill-in a survey to collect background information and to agree to the data protection policy (Appendix 3).

The chosen teachers were interviewed individually online with the conference tool "Zoom" in either German or English language according to their preferred language for the interview. The interviews took place in April and May 2024 and were solely performed by the author of this thesis. The average duration of the interviews was 30-45 minutes. All interviews were recorded with "Zoom". Two interviews were transcribed by hand, while five interviews were transcribed with the software "audapolis", for which these five teachers were asked for their consent beforehand and none of the participants refused the use of "audapolis". Transcripts of interviews conducted in German language were translated with the browser-based translator software "DeepL". All transcripts and English translations were cross-checked with the original recordings and notes multiple times to ensure accuracy and reliability of the data.

3.4 Data Analysis

The transcribed interviews were thematically analysed using the qualitative data analysis method of Miles et al. (2014) which is briefly summarized in Appendix 4 (Appendix Fig. 1) with adjusted modifications and applications deployed by Jääskä and Aaltonen (2022). According to this interactive model of qualitative data analysis, the phases of qualitative data analysis are interconnected and iterative (Miles et al., 2014). Starting with the (1) data collection during the semi-structured interviews together with the resulting transcripts (see chapter 3.3), the collected data was then (2) condensed including selection, organization and coding of the data

focusing on relevant aspects for the research focus of this study during the thematic analysis of the interviews (Jääskä & Aaltonen, 2022; Miles et al., 2014).

Data condensation was performed in several iterative steps (Appendix 4; Appendix Figure 2): (a) First, the data was pre-organized according to the pre-determined question structure and blocks and the collected observations of the interviewed educators were then coded using MAXQDA Analytics Pro software resulting in descriptive codes of the teachers' experiences and observations which were then categorized and collected in first-order categories which represent a higher categorial and abstract level of the coded data (Gibbs, 2018; Miles et al., 2014). In order to qualify as a first-order category, codes grouped as similar had to be identified at least among two out of the seven participants. (b) Following this first cycle of coding and categorizing, second-order themes were then formulated and organized to identify common motifs and patterns which summarize similar grouped first-order categories in order to direct the conclusions and the outline of the analysis (Jääskä & Aaltonen, 2022; Miles et al., 2014). (3) Accordingly, analysed data was displayed in first-order categories and second-order themes with the help of (a) tables as well as (b) collections of supplementary representative quotes substantiating the identified categories and themes from the original transcripts (Appendices 5 to 10) underlining the findings of this analysis process (Jääskä & Aaltonen, 2022). (4) Conclusions were drawn and refined from the condensated data and verification was performed by aligning and revisiting the findings and conclusions several times with the originally collected data (Jääskä & Aaltonen, 2022).

4. Results

This chapter will describe and summarize the results of the conducted study according to the presented research strategy. In line with the initial RQs, this section will first deal with general observations of game-use in higher education among the interviewed participants from STEM and life sciences (chapter 4.1) and consequently will focus on the teachers' perspectives on perceived benefits (chapter 4.2) and on perceived challenges of game-based learning (chapter 4.3), each for teachers and students.

4.1. Game-use in higher education

To begin with, game use in higher education in Germany in STEM and life sciences shows versatile conditions and starting points among the interviewed participants of this study. First of all, three out of the seven participants developed and embedded games in funded teaching

innovation or scientific projects, while one participant used the help of existing university structures (like central departments for didactical support). One participant used internal processes to develop and embed the game and two participants were supported by their institution or networks. Secondly, six out of the seven participants used digital games running either on computer and smartphone or on virtual reality (VR) glasses, while one participant used a board game, but for which a digital version is also available. Four out of the seven participants used VR as a platform for their game-use. Thirdly, six out of seven participants embedded the game-use into their teaching curriculum as part of existing teaching formats (e.g. seminars, lectures or practical courses), while one participant developed a new self-learning unit for students using different teaching methods including games. Despite mostly versatile starting points and implementations, it is possible to identify common motifs regarding the participants' motivation to use game-based learning in their specific teaching setting as described in Table 3.

Table 3: Identified themes for the motivation for the participants of using game-based learning. Corresponding, substantiating and justifying quotes and examples from the original transcripts are displayed in Appendix 5.

First-order category (Categorized Observations derived from the coded interviews)	Second-order theme (identified common motifs from first-order categories)	Exemplary quote for this theme (according to first-order categories, participant number in brackets)
Teachers use games for learning out of curiosity and personal interest.	Personal interest in games and new educational technologies.	"(...) have to say games and that was um personal curiosity first of all whether you can also use something like this for [unclear] serious teaching, i.e. beyond the pure gaming aspect but to combine the whole thing with each other in principle as a didactic tool, i.e. your own interest um but of course you also see the need um insofar as the deficits in [subject] teaching are obvious (...)" (6)
Teachers show high personal commitment to the use of their games.		
Teachers like to try and to use immersive technologies for teaching.		
Teachers use games to have the possibility of transfer and application of knowledge with their students.	Using games to exploit game characteristics for a (modern) learning approach.	"Yes, it's easy because of the deductible, I mean we had a nice PowerPoint on it before but that's just up-front again but I think because it's an extremely complex and above all dynamic matter, yes so I would use these two terms because a game is dynamic, a game changes it has ups and downs, new things move to the foreground with the new information they move to the background again (...)" (4)
Teachers choose games because they can display dynamic and complex processes.		

Two main themes can be summarized according to the data analysis: on the one hand, five out of seven teachers report their personal interest into new educational technologies (such as VR) as a driver for their implementation for game-based learning, on the other hand three out of

seven participants also state that they wanted to “exploit” game characteristics and gamified elements to establish a modern learning and teaching approach in their teaching practice.

In addition to the identified common motifs regarding the motivation of game-use in higher education among the participants, a closer look on the didactical functions and intentions teachers are pursuing with their game implementation is necessary. The analysed and identified didactical goals for the use and implementation of game-based learning are displayed in Table 4. Six out of seven participants report to use games as either a training tool to prepare the students for the contents (for example for exams or a practical courses), while four out of seven teachers also intend to offer structure to contents with their game-use. Moreover, five out of seven participants mention games as a method to offer students possibilities for the application of their (content or procedural) knowledge.

Table 4: Identified didactical goals of higher education teachers for using game-based learning. Corresponding, substantiating and justifying quotes and examples from the original transcripts are displayed in Appendix 6.

First-order category (Observations derived from the coded interviews)	Second-order theme (identified common motifs from first-order categories)	Exemplary quote for this theme (according to first-order categories, participant number in brackets)
Teachers use games as training tools for exams.	Games can act as a training tool.	"(...) and there you can imagine it in space but many students can't imagine it and there this should simply help them to have such an aha-effect and can suddenly connect the formula to the function to the representation in three dimensions." (2)
Teachers make use of games to simulate and train (complex) situations.		
Teachers use games to train abstraction and imagination skills.		
Games can create structure and enhance procedural knowledge.	Games can offer structure to contents.	"(...) the goal is actually to be better prepared for the later exercise in terms of systemic and procedural knowledge (...)" (1)
Teachers use games to convey contents.		
Teachers use games to translate knowledge into action.	Games can prepare for the profession and offer application of knowledge.	"I mean I've been working in the job for almost thirty years that's there implicitly in the back of my mind, of course, but if someone were watching me now, yes, it wouldn't be because then it wouldn't be comprehensible in my actions because it mainly takes place on a purely cognitive level and we try to make this cognitive decision-making process tactically clear in this game." (4)
Teacher use games to raise awareness for aspects of their discipline.		
Teacher use games to prepare students with skills for their later profession.		

In this regard, participants especially from medicine state that they want to contribute to the professional development of their students with games by giving them the possibility to “translate knowledge into action” (for example in simulation games), by making processes transparent (e. g. decision making) or by raising awareness for contents and (sensitive) topics of their

discipline. All participants describe a serious intention of the games use and report that they want connect their didactical intention with game or game-elements for the students.

4.2 Benefits of game-based learning for teachers and students

Firstly, it is important to mention that the data analysis resulted in partly overlapping benefits of game-based learning for teachers and students since most benefits were mentioned (and coded) in the context of benefits for students. This was a common trend among most participants to firstly (and mostly) talk about students' benefits also when explicitly asked for benefits for themselves as teachers. As shown in Table 5, the data analysis resulted in three second-order themes for benefits of game-based learning which were identified *for teachers*.

Table 5: Benefits of game-based learning for teachers from the teachers' perspective as described by the participants. Corresponding, substantiating and justifying quotes and examples from the original transcripts are displayed in Appendix 7.

First-order category (Observations derived from the coded interviews)	Second-order theme (identified common motifs from first-order categories)	Exemplary quote for this theme (according to first-order categories, participant number in brackets)
Teachers are creating a motivating and interesting environment with games.	Teachers can create an appealing and motivating environment for students and themselves.	"I think in general; games are fun. And they can be very immersive. So, that is definitely an advantage. I think you can, it's a great way to get content across." (5)
Teachers make their own teaching more interesting.		
Games are fun and immersive and cause greater interest.		
Game-use creates memorable learning moments.		
Teachers can establish a positive attitude towards their subject and topic.		
Teachers see games as a personal source of fun.	Teachers feel personal didactical enrichment with games.	"And so yes, and this game-based learning was just another new variant in my teaching portfolio, so I would describe it as an enrichment strategy for my existing teaching portfolio." (4)
Teachers experience an interesting expansion and enrichment of their own teaching methods.		
Teachers expect learning contents to last longer in memory with games.	Teachers expect games to be a source for advanced and deeper learning.	" (...) so from a course from which the students go out and say wow that was something different and that stimulated me in a completely different way, perhaps even motivated me to then, for example, after such a, to reflect on it again and then perhaps delve deeper into the topic (...)" (6)
Games induce (self-)reflection about contents.		

Six out of seven participants mentioned the creation of an appealing and motivating environment for students and themselves as a benefit of game-based learning. In this context, the creation of memorable moments with games for the students which contribute to a motivating and interesting learning environment in their teaching practice was emphasized. Furthermore,

teachers thought that games can also contribute to establishing a positive attitude towards their subject or the taught topics. Another theme (five out of seven participants) which can be summarized is the perceived (personal) didactical enrichment of the teachers' learning and teaching portfolio, also in connection with personal fun and interest in using games and new technologies in teaching. Lastly, five out of seven teachers expect games to be a source of and deeper learning enhancing long-term remembering and learning of contents as well as inducing (self-) reflection of the contents.

As mentioned previously, although asked explicitly for their perspective on benefits of game-based learning for higher education teachers (and for themselves personally as a teacher), almost all participants started reporting on benefits in their teaching practice with and for their students. The data therefore shows sometimes overlapping themes according to the identified benefits for teachers and students. Table 6 summarizes the identified themes on the explicitly extracted benefits of game-based learning from the participants' point of view *for students*.

Table 6: Benefits of game-based learning for students from the teachers' perspective as described by the participants. Corresponding, substantiating and justifying quotes and examples from the original transcripts are displayed in Appendix 8.

First-order category (Observations derived from the coded interviews)	Second-order theme (identified common motifs from first-order categories)	Exemplary quote for this theme (according to first-order categories, participant number in brackets)
Games create memorable moments.	Games offer a versatile, fun and rich in variety environment for the students.	"(...) but what students say is that this approach gives them pleasure and that they are motivated to deal with the material again afterwards because they can perhaps get into it via another dimension." (1)
Games offer different access to topics.		
Games can increase interest and motivation.		
Games offer possibilities to show practical relevance of theory.		
Games create a fun and joyful environment.		
Digital game-based learning is independent of time and space.	Digital games can give the opportunity of independent learning.	"The most important thing is that it's independent of time and space, that's it, you can do it, the students can practise on Sunday night, I don't know, in the middle of the night or on Wednesday morning, it's up to you." (3)
Games and VR enable the play of dangerous scenarios.	Students can learn in a safe-space with trial and error.	"VR is something similar to the flight simulator for me that you can try things out you can try out things that you might not be able to do in reality or, as is often the case with us, you have to practice them before we can do them in the lab before there are problems that you break something or basically endanger yourself or others." (7)
Students can learn via trial and error in a protected environment.		
Games and VR can create a safe space also for mistakes.		

Two themes were dominant in this analysis. Remarkably, all (seven out of seven) teachers described games as a means to create a versatile, fun and rich in variety environment for the students which not only offers a different access to contents and topics but also showing the practical relevance of theory. Strikingly, an overlapping first-order category appears at this point for games as a method to create memorable moments, which was also identified as a benefit for the teachers regarding their teaching practice as described previously.

The second theme is the creation of a safe-space for trial and error when using games, not only by offering training possibilities but also by manipulating things and trying out new ways of approaching problems in a protected environment with mistakes allowed. Especially the participants using VR reported this aspect as beneficial for the students since the immersive technology of a virtual reality enhances the “room” for mistakes by actually creating a virtual room. Another theme which was mentioned as a benefit by two participants is the opportunity for independent learning when using digital games independent of time and space.

4.3 Challenges of game-based learning for teachers and students

Firstly, the data analysis of the teachers' perspectives on challenges of game-based learning resulted in a remarkably higher number of second-order themes regarding challenges of game-based learning for teachers than for the reported challenges for students.

The identified challenges *for teachers* among the collected data vary from technical circumstances to didactical decision making when using game-based learning, as presented in Table 7. First of all, all teachers found it challenging to meet with the students' expectations when using game-based learning. Although most of the teachers mentioned that they have iterative evaluation steps for their courses and game (or VR projects) in which the students can report on their experiences and attitudes, some reported that it was challenging finding suitable contents for the game or finding the right “language” of the game that would fit with the students' expectations, needs as well as with the didactical objective of the game-use and course contents. Furthermore, participants also mentioned that it might be challenging to face scepticism among students for new teaching methods.

Another theme is the time expenditure of the game-use in teaching. This theme was identified among all participants, and especially emphasized by those using VR as a platform for their games regarding the technical implementation into their curriculum. Besides, a third identified theme among five out of seven participants was the diverse mindsets of colleagues. Some participants mention scepticism but also described their teams as highly motivated for the game-use and the implementation of new teaching technologies.

Table 7: Challenges of game-based learning for teachers from the teachers' perspective as described by the participants. Corresponding, substantiating and justifying quotes and examples from the original transcripts are displayed in Appendix 9.

First-order category (Observations derived from the coded interviews)	Second-order theme (identified common motifs from first-order categories)	Exemplary quote for this theme (according to first-order categories, participant number in brackets)
<p>Teachers find it sometimes challenging choosing the right contents for the games.</p> <p>Teachers find it challenging choosing the right design and structure of games to make a game suitable for the students.</p> <p>Teachers find it challenging choosing the right channels to address the students for teaching.</p> <p>Teachers might face scepticism among students when using new teaching methods or technologies like games.</p>	<p>Teachers find it challenging to meet with the students' expectations.</p>	<p>"(...) in the end, the how do you say, the proof and the putting it's just sort of giving it to the opening up to the students we see what comes and I found it challenging to know what is cringe and what works (...)" (5)</p>
<p>Teachers feel that updating and technical changes of devices for games takes (much) time to implement.</p> <p>Teachers think that use of new technologies such as VR in combination with game-based learning is currently too time consuming.</p> <p>Teachers face difficulties having enough time to implement and update games for learning.</p>	<p>Teachers experience game-based learning as time consuming.</p>	<p>"Yes now, now it takes time, technical changes always take time. In other words, it takes time to keep up with what is possible and what should be possible." (3)</p>
<p>Teachers face institutional obstacles when implementing new teaching methods such as games.</p> <p>Teachers see constraints and scepticism towards new teaching methods among colleagues.</p> <p>Teachers want to convince colleagues to be open-minded for new teaching formats and technologies such as games.</p>	<p>Teachers face different mindsets among colleagues.</p>	<p>"I actually don't like this generalization but it's a bit of a german problem that we don't need, that people should just learn properly. And the like and sometimes convince their (...) colleagues that it makes sense to deal with modern possibilities, so it doesn't mean that learning or something at the blackboard is all bad or something like that." (7)</p>
<p>Teachers face difficulties when adapting digital games on different devices.</p> <p>Teachers might face difficulties keeping the devices updated for the game use (in case of VR games).</p> <p>Teacher face problems finding suitable spaces for using VR-game-based learning.</p> <p>Teachers see a higher need for staff supervising the students during game-based learning.</p> <p>Teacher experience technical difficulties with stable WIFI-connection at their university for VR-games and digital games.</p>	<p>Teachers experience technical and organisational obstacles when implementing game-based learning.</p>	<p>"It often fails because of very primitive things that you can't get into the WIFI or the WIFI isn't good enough or something like that." (7)</p>

The last commonly identified theme among six out of seven participants are the technical and organisational obstacles when implementing game-based learning. This theme was mainly identified among the participants using VR as a game-platform, but was also mentioned by other participants using digital games (such as adapting the game to available operating systems and devices). Here, resources and internet availability were one aspect identified in the data as well as the higher need for staff supervising the students during the game-play. In this context, two participants also mentioned that digital game-based learning in self-learning units as part of self-directed learning could also lower personnel expenses and lead to more individualized and time-efficient learning for the students (and teachers). Additionally, all four participants using VR as a platform mentioned “motion sickness” as a result of the game-play in the virtual reality as a challenge for the game-use in their specific teaching setting and courses as well as challenge for the students playing the game.

For the teachers' perspective on challenges *for students*, the data analysis revealed two themes as shown in Table 8. Here, the first theme (four out of seven participants) is connected to the use of VR as a game platform, namely the overwhelming and overstimulating situation potentially induced by the use of VR. Another identified theme are the technical prerequisites which might be challenging if the students have no resources available at home e. g. to play digital games in an independent learning environment (two out of seven participants).

Table 8: Challenges of game-based learning for students from the teachers' perspective as described by the participants. Corresponding, substantiating and justifying quotes and examples from the original transcripts are displayed in Appendix 10.

First-order category (Observations derived from the coded interviews)	Second-order theme (identified common motifs from first-order categories)	Exemplary quote for this theme (according to first-order categories, participant number in brackets)
Immersive games such as in VR might overstimulate and overwhelm the students.	Games might cause an overwhelming or distracting situation.	"The problem with the subject matter is that when people are in VR for the first time, they are distracted by lots of other things, so they don't concentrate on the subject matter itself." (2)
Game features in VR might distract the students.		
Using immersive technologies such as VR is currently hard to deliver outside university.	Technical prerequisites might be challenging for the students.	"(...) which means that they have to be on site and be looked after here on site and that we have to somehow maintain and update these devices, which I see as perhaps more of a problem, so to speak, that is ultimately a delivery problem, this type of teaching is still very centralized at the moment." (6)

Almost all participants highlighted, that more research is needed to evaluate the actual learning benefit of game-based learning for students regarding their learning and academic

performance, especially when training complex situations or simulations with games. Participants involved in funded projects already performed such surveys in order to investigate and quantify the effects of the game-use in their teaching, but more data is needed. Participants also suggest to design control group studies to investigate the effects of game-based learning for their students especially with regard to academic and professional performance.

5. Discussion

The final chapter of this thesis will discuss the results and findings in the light of the initial research questions and objectives. The purpose of this study was to investigate the teachers' perspectives on game-based learning in German higher education in STEM and life sciences. Two aspects will be also highlighted separately: (1) the implications of this study for game-based learning in STEM and life sciences regarding other disciplines (chapter 5.1) as well as a special emphasis on the field of game-based learning with virtual reality (chapter 5.2).

To begin with, the initial research question RQ1 was to identify how teachers in STEM and life sciences in Germany use games for learning in their teaching practice. Despite a diverse use of games for learning with different platforms (such as digital games, VR games and board games) common motivations and didactical goals behind the game use could be identified. Especially the didactical functions found in this study are in line with theoretical foundations and previous literature, namely Jan and Gaydos (2016) (see chapter 2.1). In this thesis, common didactical goals could be found as well, especially (a) game use for training of contents and (b) games for application of knowledge also for the later profession which can be connected to the content mastery games (Jan & Gaydos, 2016). In this regard, this thesis confirmed common theoretical foundations of game-based learning also in the field of higher education. For the motivational aspects of game use, the results show that personal characteristics of the teachers (such as personal interest, curiosity or motivation) as well as the idea to “exploit” game-elements for the teaching practice to convey the contents and to make the own teaching more interesting are main drivers for game-based learning. This aspect is in line with theoretical foundations of game-based learning in learning theory (chapter 2.1.3) as well as with serious games using entertaining elements of games to teach content (serious part) as stated by Caserman et al. (2020). Here, the data generally shows that teachers are aware of the technical advances that facilitate new technologies for teaching a “digital native” younger generation of students which is also discussed in literature as an effective way for interactive and motivating learning (Anastasiadis et al., 2018). Interestingly, some games in this study explicitly target the

future profession of the students and aim to prepare them for their professional life and possible challenging situations (especially in the field of medicine) while still trying to deploy enjoyment elements to create an appealing environment for the students. This constitutes the constructivist foundation of game-based learning in the sense of “situated understandings” (Shaffer et al., 2005, p. 107). In sum, these findings do not differ from literature known concepts or studies also from other countries and therefore do not necessarily display specific characteristics of German higher education but rather general foundations of game-based learning.

The second research question RQ2 aimed to take a closer look on the benefits of game-based learning in higher education in STEM and life sciences in Germany from a teachers' point of view for teachers and students. For this research question, three striking findings of this study which are also partly reported in literature shall be highlighted. (a) First of all, teachers feel personal didactical enrichment with games according to the results of this thesis. Similar effects were described before by Jääskä and Aaltonen (2022) who stated that teachers feel motivated and inspired when using games (Jääskä & Aaltonen, 2022), but especially participants in this study using VR continuously reported the perceived high potentials of their application when using games in VR. (b) In addition to that, teachers also state for themselves as well as for the students that game-based learning can create motivating environments and memorable moments which consequently might lead to an enhancement of deeper learning and a (more) positive attitude towards their subject or the contents. These findings are in accordance with Crocco et al. (2016) who found that enjoyment is correlated with deep learning and games might reduce anxiety during the learning process (Crocco et al., 2016). (c) The identified use of games to create a safe space for trial and error is corresponding to existing pedagogical foundations (Toh & Kirschner, 2020). This aspect was especially highlighted by participants using VR in their teaching practice as well as by participants who use games as tools to prepare students for exams or later professional situations.

The third and last research question RQ3 aimed to investigate the challenges of game-based learning in German higher education in STEM and life sciences from a teachers' point of view for teachers and students. To begin with, the identified challenges for teachers as perceived by themselves mainly concern technical and time critical issues, which is mainly in line with previous findings by Jääskä and Aaltonen (2022) and Sánchez-Mena & Martí-Parreño (2017) who both identified the time consumption of establishing game-based learning as barrier and challenge (Jääskä & Aaltonen, 2022; Sánchez-Mena & Martí-Parreño, 2017). Similar to their study, this thesis also found that implementing and using game-based learning can create extra work and time needed for the teachers. Most strikingly, the identified challenge of teachers in

having to trouble to meet with the students' expectations for a suitable game use in their teaching can also be found with Jääskä and Aaltonen (2022) and also Sánchez-Mena & Martí-Parreño (2017) who both state this is a (major) challenge especially in the process of didactical decision making choosing a game and game-contents, also in the light of students refusing game-based learning and preferring rather traditional teaching methods (Sánchez-Mena & Martí-Parreño, 2017). Arguing for a more teacher-oriented offer of universities to address and overcome these obstacles in using game-based learning, iterative steps establishing games and continuously consulting with the students can be emphasized, which was also done by almost all of the participants of this study. Fernández-Raga et al. (2023) in this sense propose a framework for implementing game-based learning and overcoming possible obstacles including several steps such as evaluating necessary skills of the students to for game-play before game-use (Fernández-Raga et al., 2023). Applying such systematic frameworks could be a possible way to face the challenges in meeting with the students' expectations. In addition to that, not surprisingly, technical issues and problems as well as resources (like financing) were also found to be challenging for teachers when using game-based learning, which is also in line with previous findings by Jääskä and Aaltonen (2022). For the students, the participants of this study assume that games might cause overwhelming and distracting situations which matches with previous literature (Jääskä & Aaltonen, 2022; Sánchez-Mena & Martí-Parreño, 2017). Interestingly, two participants mentioned Artificial Intelligence (AI) as either a challenge or as a new source of innovation for game-based learning. The effects and implications of AI for game-based learning were not part of this thesis but might open new possibilities for further investigations.

5.1 “No difference?”: Teachers' perspectives in STEM and Life Sciences

Most strikingly, by comparing the results of this thesis to literature known challenges and opportunities of game-based learning (Jääskä & Aaltonen, 2022; Sánchez-Mena & Martí-Parreño, 2017), it becomes obvious that the identified challenges of teachers in STEM and life sciences in German higher education do not differ much from teachers of other disciplines or from different countries. This is to some extent surprising since it could have been hypothesized that interviews with teachers from these disciplines might have shown specific discipline-related challenges, but this is not the case for this study. Further investigations are needed to confirm and verify this finding. Comparing the findings of this thesis in higher education with findings from other educational levels like secondary schools reveal many similarities of identified benefits and challenges. Huizenga et al. (2017) investigated the perceived usefulness of digital games by secondary school teachers and found increased student engagement (like enthusiasm),

increased motivation to learn and supporting learning outcomes as perceived useful aspects of game-based learning by their participants (Huizenga et al., 2017), which is also in accordance with the results of this thesis. The authors therefore conclude, that more research is needed to make the perceived useful aspects of game-based learning visible to teachers and to offer deeper insights how these perceived useful aspects of (digital) games affect student learning (Huizenga et al., 2017). This also applies for this study with higher education teachers (as mentioned by some participants) that more research is needed to estimate the effects of game-based learning on student learning performance highlighting the need for more empirical data. It also emphasizes the appropriate situatedness and implementation of games through pedagogical premises and planning in order to make games suitable for teaching and learning settings (Young et al., 2012). Despite efforts to formulate a framework in which the effects of game-based learning can be assessed in comparison to rather “conventional” or “traditional” methods, it is important to mention that standardized evaluation systems to evaluate such effects are missing to date (Xu et al., 2023) and might be necessary for future research in the field of game-based learning.

Another critical issue of this thesis is the local delimitation to higher education teachers working at universities in Germany. One of the participants identified different mindsets towards game-based learning and the use of new technologies such as VR among their institutions and colleagues as a partly “German” problem. In fact, literature shows that spreading new teaching methods in higher education is actually a common identified challenge (Smith, 2012). Smith (2012) found in their literature review that environments that stimulate and facilitate innovative learning are important to establish new and innovative teaching approaches (in general, not specifically for game-based learning), which also includes support of senior staff for new innovations as well as (supporting) necessary skills of students and teachers to use and implement new teaching approaches (Smith, 2012). In consequence, “mindset” as identified in this study is not a specific theme for German higher education or game-based learning, but rather shows a general problem establishing new learning approaches in higher education (Smith, 2012).

To sum it up, the results of this thesis confirm previous findings especially by Jääskä and Aaltonen (2022) and Sánchez-Mena & Martí-Parreño (2017). Therefore, the findings might contribute to a better understanding of challenges and benefits of game-based learning in higher education settings and also offer insight into teachers' perspectives for policy makers.

5.2 “Innovative platform?”: Virtual reality for game-based learning

Since four out of seven participants used virtual reality as a platform for their game-use a closer look on the challenges especially in the context of VR is necessary. Besides technical difficulties

and resources as challenges connected with VR use, participants highlight the immersive character of VR to convey contents and to create an actual virtual space for games. In this context, participants underline the benefits especially of VR to create complex and “realistic” scenarios for the students not only supporting their knowledge but offering a safe space to perform their knowledge and to apply it. Udeozor et al. (2023) also highlight this advantage of VR in connection with (self-) assessment of the students and gaining new skills (e.g. collaborative skills) (Udeozor et al., 2023). Alper et al. (2021) summarize the potential of game-based learning in augmented reality mainly regarding motivational aspects and positive effects for collaborative work and self-learning (Alper et al., 2021). The results of this thesis therefore also emphasize promising and innovative potentials of VR use in higher education in the context of game-based learning. Nonetheless, it has to be highlighted that the purpose of this study was not to investigate the potentials of VR itself for higher education in STEM and life sciences but to investigate game-use and game-based learning. The results nevertheless show that the synthesis of both, VR and games, might lead to an innovative teaching approach which has to be investigated further, either focusing just on VR or explicitly addressing VR games for education.

5.3 “A real game-changer?!”: Conclusions, Limitations and Outlook

In sum, the initially stated research questions as presented in chapter 2.3 could be answered. Moreover, the results of the thesis contribute to a better understanding of the teachers' perspective on game-based learning in higher education by specifically addressing challenges and benefits of game-based learning for teachers and students from a teachers' point of view in the light of previous literature. Strikingly, this thesis explicitly addressed teachers from higher education institutions who already have used or implemented game-based learning in their actual teaching practice with university students, which is in contrast to a previous study conducted by Jääskä and Aaltonen (2022). Therefore, this thesis might contribute to a more specific understanding of challenges and benefits. Here, it is important to highlight that this thesis only investigated the teachers' perspectives and their impressions and experiences (and not collecting data from students). Additionally, by specifically choosing teachers from STEM and life sciences, this study ought to initiate a deeper understanding of possible discipline-specific problems although the results show that their perspective in these disciplines do not differ much from previous known challenges from other higher education disciplines or educational levels.

Despite the overall contribution of this thesis, there are important limitations of this study. First of all, the sample size is rather small to draw founded generalized conclusions for the initial research questions, although the data analysis clearly underlines that common themes

and motifs can be identified among the participants. Another critical issue is the representation of all STEM disciplines and life sciences. The sample of this thesis shows an overrepresentation of life sciences (medicine and biology), so follow-up studies specifically including more participants from mathematics, science (physics and chemistry) as well as engineering and informatics might be necessary in order to ensure a specific perspective of these subjects. Choosing a qualitative approach to the topic offers an in-depth but also personal view of the participants on the topic. To gain deeper insights, possible follow-up studies to this thesis could include systematic surveys among a larger number of participants. Also extending the sample size for semi-structured interviews with higher education teachers in STEM and life sciences from more countries might offer a deeper and international perspective. Another follow-up study could focus on the use of games in virtual reality in order to get a better understanding of immersive technologies in higher education, besides the didactical and pedagogical approach of game-based learning. Overall, this study highlights that innovative and experimental teaching approaches are perceived and evaluated critically among higher education teachers so more research is needed to understand these perspectives and mindsets which should result in clear instructions and teacher trainings to enhance innovative learning and teaching approaches.

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Authors' Declaration

I hereby declare that I have written this thesis independently and that all contributions of other authors and supporters have been referenced. The thesis has been written in accordance with the requirements for graduation theses of the Institute of Education of the University of Tartu and is in compliance with good academic practices.

Signature (Julian Schoth)

Date

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Appendix 1 – Interview Questions

Questions (Eng/Ger)	Blocks
<p>Please describe briefly, how do you implement games (for learning) in your teaching practice?</p> <p><i>Bitte beschreiben Sie kurz, wie Sie Sie (Lern-)Spiele in Ihrer Lehr-Praxis einsetzen.</i></p>	<p style="text-align: center;">I</p> <p style="text-align: center;">Understanding of Game-based Learning and Expectations</p>
<p>Please explain, what is or was the didactical and pedagogical function of the game(s) in your described teaching practice?</p> <p><i>Bitte erläutern Sie, welche didaktische und pädagogische Funktion das/die Spiel(e) in Ihrer beschriebenen Lehrpraxis haben bzw. hatten?</i></p>	
<p>What was your motivation and intention to implement games (for learning) in your teaching practice?</p> <p><i>Was waren ihre Motivation und ihre Absicht, (Lern-)Spiele in Ihrer Lehr-Praxis einzusetzen?</i></p>	
<p>Please describe the process how you planned your implementation of games (for learning) in your teaching including your personal development and the (possible) help support of your institution.</p> <p><i>Bitte beschreiben Sie den Prozess wie Sie den Einsatz von (Lern-)Spielen in Ihrer Lehre geplant haben auch mit Blick auf Ihre persönliche Entwicklung und die (möglich) Hilfe und Unterstützung durch Ihre Einrichtung/Universität.</i></p>	
<p>From your perspective and experiences, what are (possible) benefits of game-based learning for teachers in teaching in higher education for you personally and in general?</p> <p><i>Aus Ihrer Sicht und aufgrund Ihrer Erfahrungen, was sind (mögliche) Nutzen und Vorteile des „game-based learnings“ für Lehrende in der Hochschulbildung für Sie persönlich und im Allgemeinen?</i></p>	<p style="text-align: center;">II</p> <p style="text-align: center;">Observations: Benefits and Opportunities for teachers</p>
<p>From your perspective and experiences, what are (possible) challenges of game-based learning for teachers in teaching in higher education for you personally and in general?</p> <p><i>Aus Ihrer Sicht und aufgrund Ihrer Erfahrungen, was sind (mögliche) Herausforderungen des „game-based learnings“ für Lehrende in der Hochschulbildung für Sie persönlich und im Allgemeinen?</i></p>	<p style="text-align: center;">III</p> <p style="text-align: center;">Observations: Challenges for teachers</p>
<p>From your perspective and experience, how do you perceive (possible) benefits of game-based learning in teaching in higher education in your specific teaching situation for your students?</p> <p><i>Aus Ihrer Sicht und aufgrund Ihrer Erfahrungen, wie nehmen Sie (mögliche) Nutzen und Vorteile des „game-based learnings“ für Ihre Studierenden in Ihrer speziellen Lehr-Situation wahr?</i></p>	<p style="text-align: center;">IV</p> <p style="text-align: center;">Observations: Benefits and Opportunities for students</p>
<p><u>Follow-Up Question:</u> Please describe, how you perceive the development of competencies and skills of your students using games (for learning).</p> <p><i>Bitte beschreiben Sie, wie Sie Entwicklung von Kompetenzen und Fähigkeiten Ihrer Studierenden mit (Lern-)Spielen wahrnehmen.</i></p>	

<p>From your perspective and experience, how do you perceive (possible) challenges of game-based learning in teaching in higher education in your specific teaching situation for your students?</p> <p><i>Aus Ihrer Sicht und aufgrund Ihrer Erfahrungen, wie nehmen Sie (mögliche) Herausforderungen des „game-based learnings“ für Ihre Studierenden in Ihrer speziellen Lehr-Situation wahr?</i></p>	<p style="text-align: center;">V</p> <p style="text-align: center;">Observations:</p> <p style="text-align: center;">Challenges for students</p>
<p><u>Follow-Up Question:</u> Please describe, how you perceive your students' engagement and motivation when using games (for learning) in your teaching practice.</p> <p><i>Bitte beschreiben Sie, wie Sie das Engagement und die Motivation Ihrer Studierenden wahrnehmen, wenn Sie (Lern-)Spiele in Ihrer Lehr-Praxis einsetzen.</i></p>	

Appendix 2 – Introductory Text for the interviews

English Introductory Text

Dear participant,
thank you very much for your participation in the interviews for my master thesis on challenges and opportunities of game-based learning in higher education in STEM and life sciences in Germany. The aim of this study is to evaluate challenges, opportunities and benefits of game-based learning from an educators' point of view. The following interview is semi-structured which means, that you have the opportunity to speak freely about your experiences and perspectives on the topic. You are welcome to ask questions in case you do not understand a question or a topic of the interview. I would like to invite you, to answer the questions as detailed as possible since this interview is meant to be an open discussion in a safe academic space. This interview is recorded and will be completely transcribed for further analysis. Your data will be strictly protected and your answers will only be published anonymously. No original recordings of this interview will be published online, only transcripts and representative quotes will be part of the thesis. The thesis will be published publicly available online under the rules and regulations of the University of Tartu in Estonia.

German Introductory Text

Liebe Teilnehmerin, lieber Teilnehmer,
vielen Dank für Ihre Teilnahme an den Interviews für meine Masterarbeit über die Herausforderungen und Chancen des spielbasierten Lernens in der Hochschulbildung in MINT und Lebenswissenschaften in Deutschland. Das Ziel dieser Studie ist es, die Herausforderungen, Chancen und Vorteile von Game-based Learning aus der Sicht von Lehrenden zu untersuchen. Das folgende Interview ist halbstrukturiert, was bedeutet, dass Sie die Möglichkeit haben, frei über Ihre Erfahrungen und Perspektiven zum Thema zu sprechen. Sie können gerne Fragen stellen, falls Sie eine Frage oder ein Thema des Interviews nicht verstanden haben. Ich möchte Sie bitten, die Fragen so detailliert wie möglich zu beantworten, da dieses Interview eine offene Diskussion in einem sicheren akademischen Raum sein soll. Dieses Interview wird aufgezeichnet und für die weitere Analyse vollständig transkribiert. Ihre Daten werden streng geschützt und Ihre Antworten werden nur anonymisiert veröffentlicht. Es werden keine Originalaufnahmen dieses Gesprächs online veröffentlicht, sondern nur Transkripte und repräsentative Zitate, die Teil der Masterarbeit sein werden. Die Abschlussarbeit wird gemäß den Regeln und Vorschriften der Universität Tartu in Estland online öffentlich zugänglich gemacht.

Appendix 3 – Survey Background Information about participants

Interview "Game-Based Learning in STEM and Life Sciences in Higher Education"

Dear Participant,
thank you very much for your participation in the interviews for my Master-Thesis "A real game changer?!" - Educators' Perspectives on challenges and opportunities of game-based learning in STEM and Life Sciences in Higher Education in Germany" (Author: Julian Schoth) at the University of Tartu (Estonia).

The following survey collects basic data about the participants which will be used for background-information in the thesis. **Please fill out the survey latest until one day before the interview.**

Information which will be published publicly visible in the thesis is marked with **"public"**, information which will be anonymous and not be published publicly is marked with **"anonymous"**.

Data Protection Policy:
The interviews are conducted via Zoom under the regulations of European Union Data Protection Policies. The interviews are recorded (video and audio) using the Zoom recording function and are saved locally on my personal computer without the use of Zoom Cloud Services. The Recordings are transcribed into text only by hand and will be fully anonymized (no names, no names of institutions etc.). The transcripts will be part of the master thesis and can be published publicly available online according to the rules of the University of Tartu.

Thank you very much!

[In Google anmelden, um den Fortschritt zu speichern. Weitere Informationen](#)

Name and Surname (anonymous) (referred to in the Thesis as "Participant X" -> X = number from 1 to 10)

Meine Antwort: _____

Gender (anonymous)

Female

Male

Divers

Prefer not to say

Name of University (anonymous) (referred to in the Thesis as "University Y" -> Y = any letter of the alphabet)

Meine Antwort: _____

Current position (public)

Professor

Scientific Staff (Wissenschaftliche/r Mitarbeiter/in)

Academic Member (Akademische/r Rat/Rätin oder Oberrat/rätin)

Sonstiges: _____

Area of Discipline (public)

Mathematics

Engineering

Chemistry

Physics

Biology

Medicine

Sonstiges: _____

Preferred language of the interview (anonymous)

English

German

I read the data protection policy for the participation in the interviews (mentioned above) of the Master Thesis "A real game changer?!" - Educators' Perspectives on challenges and opportunities of game-based learning in STEM and Life Sciences in Higher Education in Germany" by Julian Schoth and I accept them. If you have concerns or would like to adjust the policy, please contact Julian Schoth via E-Mail.

I accept the data protection policy of the interviews.

I want to adjust the policy and contact Julian Schoth.

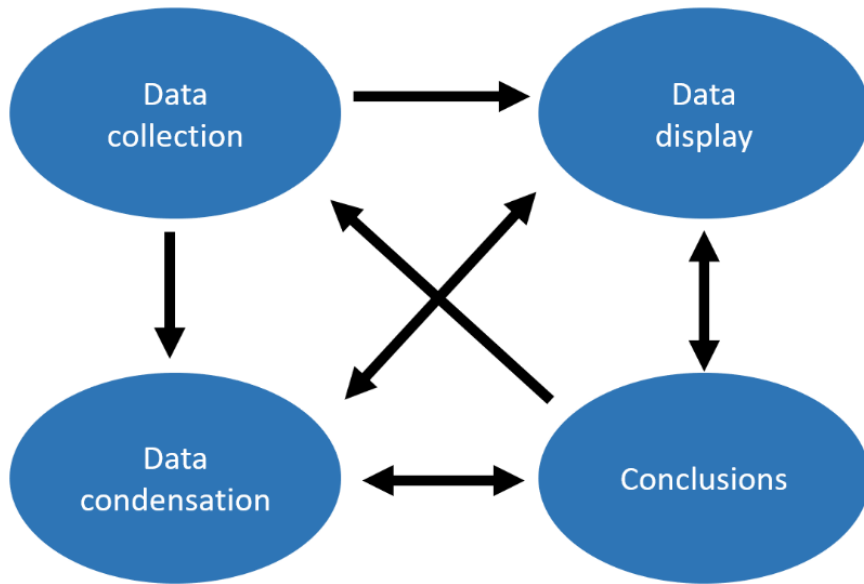
[Alle Eingaben löschen](#)

Geben Sie niemals Passwörter über Google Formulare weiter.

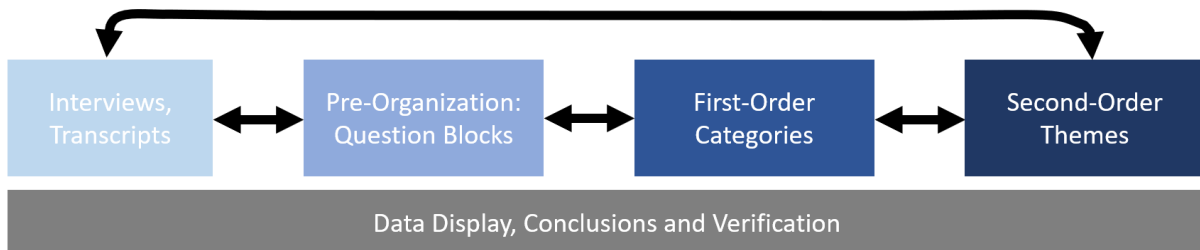
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Google Formulare

Appendix 4 – Model of qualitative data analysis by Miles et al. (2014)



Appendix Figure 1: Model of data analysis applied in this thesis. The interactive model of qualitative data analysis is interconnected and iterative (displayed by arrows). Figure was derived and modified from: Miles et al. (2014, p. 10).



Appendix Figure 2: Process of data condensation and analysis applied in this study. The scheme summarizes the iterative process of data condensation in connection with data display, conclusions and verification. This model was derived and modified from: Jääskä & Aaltonen (2022) and Miles et al. (2014) (own figure and representation).

Appendix 5 – Representative quotes underlining the identified categories and themes for table 3

Appendix to table 3: Identified first-order categories for the motivation of using game-based learning for the participants and corresponding quotes (including participant number).

First-order category (Observations derived from the coded interviews)	Quote (derived from the original transcripts)	Participant
Teachers use games for learning out of curiosity and personal interest.	"(...) have to say games and that was um personal curiosity first of all whether you can also use something like this for [unclear] serious teaching, i.e. beyond the pure gaming aspect but to combine the whole thing with each other in principle as a didactic tool, i.e. your own interest um but of course you also see the need um insofar as the deficits in [subject] teaching are obvious (...)"	6
Teachers show high personal commitment to the use of their games.	"(...) yes well, it's my baby now, no i've helped develop it and then you want to show it and i'll go along with that (...)"	2
Teachers like to try and to use immersive technologies for teaching.	"(...) but what I thought was great was that you could also see it not because I thought pokémon was so good but I saw what kind of capacities it opened up, what kind of enthusiasm you can trigger through this playfulness and that really haunted me back then with pokémon we can't do that for teaching that we could create just as much hype so that people learn their subject with enthusiasm (...)"	7
Teachers use games to have the possibility of transfer and application of knowledge with their students.	"(...) so in [subject] teaching certain aspects are neglected so far in traditional teaching traditional [subject] teaching it is very I would say very theoretical very fact-based and comparatively little application or little practical relevance so first of all because you have to acquire this whole basis first in order to then say there say at some point then to accomplish this transfer performance and that was not just trying to come in professional life but already during the study (...)"	6
Teachers choose games because they can display dynamic and complex processes.	"Yes, it's easy because of the deductible, I mean we had a nice PowerPoint on it before but that's just up-front again but I think because it's an extremely complex and above all dynamic matter, yes so I would use these two terms because a game is dynamic, a game changes it has ups and downs, new things move to the foreground with the new information they move to the background again (...)"	4

Appendix 6 – Representative quotes underlining the identified categories and themes for table 4

Appendix to table 4: Identified first order categories for didactical goals of higher education teachers for using game-based learning and corresponding quotes (including participant number).

First-order category (Observations derived from the coded interviews)	Quote (derived from the original transcripts)	Participant
Teachers use games as training tools for exams.	"The quiz that was then added, um, that's just a kind of training tool (...)"	3
Teachers make use of games to simulate and train (complex) situations.	"(...) there's a scenario with a patient and you have to approach this situation, so to speak, which is an emergency situation and basically work out certain yes, certain certain certain points to get to the solution, come to a solution or at least to an approximation of the solution and serious insofar as here in this game a 3D patient avatar, so to speak, can potentially be harmed if you don't play the game well or don't fulfill the corresponding points there (...)"	6
Teachers use games to train abstraction and imagination skills.	"(...) and there you can imagine it in space but many students can't imagine it and there this should simply help them to have such an aha- effect and can suddenly connect the formula to the function to the representation in three dimensions."	2
Games can create structure and enhance procedural knowledge.	"(...) the goal is actually to be better prepared for the later exercise in terms of systemic and procedural knowledge (...)"	1
Teachers use games to convey contents.	"(...) but to answer specifically so conveying content is definitely a very important thing, but at the same time maybe deepening the content again, so especially if you have just done something that you have the chance to repeat something again (...)"	7
Teachers use games to translate knowledge into action.	"(...) they have certainly already acquired their factual knowledge up to then in a kind of transfer performance then to the, to apply it, i.e. to retrieve it in a situation-related and suitable way and translate it into an action (...)"	6
Teacher use games to raise awareness for aspects of their discipline.	"It is, it's much much less about learning content but raising awareness all the different areas (...)"	5
Teacher use games to prepare students with skills for their later profession.	"I mean I've been working in the job for almost thirty years that's there implicitly in the back of my mind, of course, but if someone were watching me now, yes, it wouldn't be because then it wouldn't be comprehensible in my actions because it mainly takes place on a purely cognitive level and we try to make this cognitive decision-making process tactically clear in this game."	4

Appendix 7 – Representative quotes underlining the identified categories and themes for table 5

Appendix to table 5: First-order categories for the benefits of game-based learning for teachers as described by the participants and corresponding quotes (including participant number).

First-order category (Observations derived from the coded interviews)	Quote (derived from the original transcripts)	Participant
Teachers are creating a motivating and interesting environment with games.	"The first advantage, um, so of course I want my students to enjoy coming to my course, yes, and that they have the feeling that they are getting something positive out of it."	3
Teachers make their own teaching more interesting.	"(...) and that I also have to explain it at this point via new content which in turn has the advantage that I then try as a teacher to make students curious about something new that I myself am enthusiastic about. It has a bit of a montessori effect simply by demonstrating a bit and somehow you still find the fun (...)"	1
Games are fun and immersive and cause greater interest.	"I think in general; games are fun. And they can be very immersive. So, that is definitely an advantage. I think you can, it's a great way to get content across."	5
Game use creates memorable learning moments.	"And in my opinion this is achieved, by offering very descriptive perhaps also, perhaps also in parts emotionalized teaching, um, so from a course from which the students go out and say wow that was something different and that stimulated me in a completely different way (...)"	6
	"You just have variety um that's just a point that the students will probably still remember years later not just the boring [subject] lecture with new material and exercises but do you remember we also did something with vr back then that just so the lecture itself if even more remains in your head."	2
Teachers can establish a positive attitude towards their subject and topic.	"(...) that I want to say that it is clearly a completely different enthusiasm for the subject (...)"	7
Teachers see games as a personal source of fun.	"It was fun, I learned a lot (...)"	5
Teachers experience an interesting expansion and enrichment of their own teaching methods.	"And so yes, and this game-based learning was just another new variant in my teaching portfolio, so i would describe it as an enrichment strategy for my existing teaching portfolio."	4
Teachers expect learning contents to last longer in memory with games.	"(...) and the second thing is of course that it stays much more in my memory when i have done it and have been successful and have managed to do it (...)"	7
Games induce (self-)reflection about contents.	" (...) so from a course from which the students go out and say wow that was something different and that stimulated me in a completely different way, perhaps even motivated me to then, for example, after such a, to reflect on it again and then perhaps delve deeper into the topic (...)"	6

Appendix 8 – Representative quotes underlining the identified categories and themes for table 6

Appendix to Table 6: First-order categories for benefits of game-based learning for students from the teachers' perspective as described by the participants and corresponding quotes (including participant number).

First-order category (Observations derived from the coded interviews)	Quote (derived from the original transcripts)	Participant
Games create memorable moments.	"Well I'm now thinking about this other little thing just during the lesson you just have variety um that's just a point that the students will probably still remember years later not just the boring [subject] lecture with new material and exercises but do you remember we also did something with vr back then that just so the lecture itself if even more remains in your head."	2
Games offer different access to topics.	"(...) but what students say is that this approach gives them pleasure and that they are motivated to deal with the material again afterwards because they can perhaps get into it via another dimension."	1
Games can increase interest and motivation in a topic.	"There are other, let's say game-like elements that I do, and of course that also has to do with motivation."	3
Games offer possibilities to show practical relevance of theory.	"(...) enabling the students to get theory with practical relevance in a learning environment as a whole, um, exactly, that's, that's the advantage there, yes."	6
Games create a fun and joyful environment.	"I see the advantage in the fact that the students are more motivated and have more fun with it and it might stick better as a result."	2
Digital game-based learning is independent of time and space.	"The most important thing is that it's independent of time and space, that's it, you can do it, the students can practise on Sunday night, I don't know, in the middle of the night or on Wednesday morning, it's up to you." "(...) and this is for all online learning or self-learning content online-content is that it's accessible at any time. So people don't have to turn up and they were sit at home and they do it (...)"	3 5
Games and VR enable the play of dangerous scenarios.	"(...) you would rather have tried out beforehand and hope that it never happens but you should be prepared and in the laboratory you can of course you can also use things like that so that you can try out something that goes wrong or something like how do I react how do I do what do I do and then you can just test it without anything happening to anyone (...)"	7
Students can learn via trial and error in a protected environment.	"(...) I have the advantage of a different approach to a topic compared to the usual forms of teaching and other approaches, protocol or teaching mediation and have another possibility of self-reflection and can repeat x times can do it myself (...)"	1

Games and VR can create a safe space also for mistakes.	"VR is something similar to the flight simulator for me that you can try things out you can try out things that you might not be able to do in reality or, as is often the case with us, you have to practice them before we can do them in the lab before there are problems that you break something or basically endanger yourself or others."	7
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Appendix 9 – Representative quotes underlining the identified categories and themes for table 7

Appendix to table 7: First-order categories for the challenges of game-based learning for teachers as described by the participants and corresponding quotes (including participant number).

First-order category (Observations derived from the coded interviews)	Quote (derived from the original transcripts)	Participant
Teachers find it sometimes challenging choosing the right contents for the games.	"(...) in the end, the how do you say, the proof and the putting it's just sort of giving it to the opening up to the students we see what comes and I found it challenging to know what is cringe and what works (...)"	5
Teachers find it challenging choosing the right design and structure of games to make a game suitable for the students.	"But I'm not sure whether the students would rather have this tile structure with the quiz, or whether they'd rather have a quiz with an image-filling format adapted to cell phones."	3
Teachers find it challenging choosing the right channels to address the students for teaching.	"(...) it is always a challenge when students generally say no, that's no good for me i just prefer to have it on the blackboard on the other hand, that is also an attitude that you simply have to accept from our experience from everyday project work and should accept that the form of teaching is very individual (...)"	1
Teachers might face scepticism among students when using new teaching methods or technologies like games.	"(...) some people won't always like it and won't want to do it that way. There are certainly also students who say 'we don't want to play games here now' they just want to get, they just want to be presented with what's important for the next exam and don't want to play some kind of stupid game (...)"	7
Teachers feel that updating and technical changes of devices for games takes (much) time to implement.	"Yes now, now it takes time, technical changes always take time. In other words, it takes time to keep up with what is possible and what should be possible."	3
Teachers think that use of new technologies such as VR in combination with game-based learning is currently too time consuming.	"Yes, and the disadvantage I see is that it is currently still too time-consuming and is associated with too many technical aspects that you can't yet use it so spontaneously in teaching you still need a different infrastructure."	2
Teachers face difficulties having enough time to implement and update games for learning.	"This is because, I mean it's not that I'm a complete digital idiot, but, I mean every system you use, you have to learn, and, it's not something, I used on a daily basis or use on a daily basis far from, so when I have to update the thing, I have to teach myself again, because, I will have all forgotten about it how it works, so, it costs a lot of time, that is I think the main issue."	5
	"There we come to another problem my own time for all this somehow because yes I would need forty-eight hours and then	7

	preferably twenty-four hours for the other things to do or something and there it hooks a bit."	
Teachers face institutional obstacles when implementing new teaching methods such as games.	"(...) higher education policy issue of how do I get new technologies, new teaching methods implemented at the university in such a way that others who are skeptical but take a look can do it and others who are innovators can then perhaps join in immediately. So, unfortunately, there are always these administrative structural hurdles at universities."	1
Teachers see constraints and scepticism towards new teaching methods among colleagues.	"I just see that with my colleagues it's rather difficult because then it's a new thing again, you have to restructure your lecture again, you have to plan time for it to bring it in okay there we are right at the disadvantages. Maybe I'm there now, I'm predetermined, I'm biased I would say because I helped develop this module I want to show it and want to convince people that it's good. But I've just realized that I can't manage to quickly say to my colleagues 'oh come on, use it'. You're already in your old ways and you have your own concepts and your own programs that you then use to convey the topic."	2
Teachers want to convince colleagues to be open-minded for new teaching formats and technologies such as games.	"I actually don't like this generalization but it's a bit of a German problem that we don't need, that people should just learn properly. And the like and sometimes convince their (...) colleagues that it makes sense to deal with modern possibilities, so it doesn't mean that learning or something at the blackboard is all bad or something like that. But it just means that I like the term extended reality better, because I can do things with new possibilities and that's why I've never had any problems with gaming."	7
Teachers face difficulties when adapting digital games on different devices.	"Yes, so the challenges are the different platforms, whether you have iOS or Android. Because some of the apps run on one and not on the other."	3
Teachers might face difficulties keeping the devices updated for the game use (in case of VR games).	"(...) and that we have to somehow maintain and update these devices, which I see as perhaps more of a problem (...)"	6
Teachers face problems finding suitable spaces for using VR-game-based learning.	"(...) and then also to find adequate space for it that is a huge problem with the I'm really saying in brackets now supposed lack of space at universities. My thesis now is we actually have enough space at universities that is just not used synergistically."	1
Teachers see a higher need for staff supervising the students during game-based learning.	"(...) the challenges are when you think of the game, a seminar size is usually about 18-20 students and the, so the board game variant when we used to play that, that must, you need at least two or three lecturers because otherwise the students don't get to play (...)"	4
Teachers experience technical difficulties with stable WIFI-connection at their university for VR-games and digital games.	"It often fails because of very primitive things that you can't get into the wifi or the wifi isn't good enough or something like that."	7

Appendix 10 – Representative quotes underlining the identified categories and themes for table 8

Appendix to Table 8: First-order categories for challenges of game-based learning for students from the teachers' perspective as described by the participants and corresponding quotes (including participant number).

First-order category (Observations derived from the coded interviews)	Quote (derived from the original transcripts)	Participant
Immersive games such as in VR might overstimulate and overwhelm the students.	"(...) in these immersive learning worlds you are of course exposed to many, many stimuli at first, it may perhaps overwhelm you at first. The perhaps different possibilities that the whole thing is three-dimensional at first and the challenge to find your way around there first, to explore the possibilities (...)"	6
Game features in VR might distract the students.	"The problem with the subject matter is that when people are in vr for the first time, they are distracted by lots of other things, so they don't concentrate on the subject matter itself."	2
Using immersive technologies such as VR is currently hard to deliver outside university.	"(...) which means that they have to be on site and be looked after here on site and that we have to somehow maintain and update these devices, which I see as perhaps more of a problem, so to speak, that is ultimately a delivery problem, this type of teaching is still very centralized at the moment."	6

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