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Introducing Teacher Education Students to Escape Room as a Didactic Tool in Mathematics.

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Abstract: The aim of this study is to understand teacher education students' experience with an introduction to use of escape room as a didactic tool in mathematics, and to gain insight on the impact of such an introduction on teacher education students' development as mathematics teachers. Escape room is a new, game-based, didactic tool in school that offers teachers new possibilities in the mathematics classroom. Twelve teacher education students participated in the study, and data were collected through a qualitative survey, observation, and focus-group interviews. The data were analyzed through use of a framework based on game-based learning and on Dewey's perspective about what to learn and how to learn. The findings show that use of escape room in mathematics teaching was met from a traditional perspective on teaching and learning by the teacher education students, but that they showed glimpses of willingness and curiosity about its use in mathematics in school. The findings also generated hypotheses and probable conclusions that, in relation to Klafki's theory of categorical bildung, offer some understanding of possible influence on teacher education students' development of bildung as mathematics teachers, and their possible position as future change agents for mathematics teaching in school.

Keywords: Escape room, mathematics, teacher education students, bildung.

INTRODUCTION

"The aim of education is to enable individuals to continue their education" (Dewey, 1916, p. 56). The Organisation for Economic Co-operation and Development (OECD) (2019) emphasizes the future importance of citizens to be able to understand, interpret and apply knowledge and skills in various situations, and therefore that one must learn to navigate through unfamiliar contexts. Escape rooms are live-action, team-based games in which the players discover clues, solve puzzles, and accomplish tasks to complete a mission in a limited amount of time (Nicholson, 2015). A review of 70 research articles on the use of escape room in education showed that escape room

has been adopted in teaching, both for emphasis on the participants' encountered need for application of subject area knowledge and skills, and for emphasis on necessity of cooperation and trust in co-participators' competence (Taraldsen et al., 2020).

Mathematics is a mandatory subject in primary and secondary school all over the world, and some countries are already introducing new sets of methodologies in the teaching of mathematics to meet the expectations for future schooling (European Schoolnet, 2018). In Norway, for instance, the recent revision of the national curriculum gives explicit attention to problem-solving (Udir, 2019). Polya (1981, p. 117) defines problem-solving as: "to search consciously for some action appropriate to attain a clearly conceived, but not immediately attainable, aim." According to Schoenfeld (1993) problem-solving competence is about applying mathematical concepts, methods and relations in order to solve problems. Such an action-oriented understanding of competence implies that competence does not show itself as something one has knowledge about, but as something one can put into action. The escape room idea is based on emphasis of features that provide such opportunities for the participants in an escape room event. Herein lays the novelty of use of escape room in mathematics teaching and learning. The pupil is given the opportunity to display problem-solving competence within a context that is experienced as both playful and meaningful. Within educational research we see a steady increase in the use of escape room as a didactic tool, within various contexts. Escape rooms are, for instance investigated as an active methodological approach for the purpose of teaching mathematics (Alabdulaziz, 2023; Charlo, 2020; Fuentes-Cabrera et al., 2020), or used for explicit attention to mathematical subjects, like for instance Andrews and Bagdasar's (2023) emphasis on geometry and Jiménez et al.'s (2020) focus on algebra. One also finds explicit attention to authentic scenarios related to vocational education, like for instance within professional nursing practice (Morell et al., 2020), computer security (Béguin et al., 2019), and forensic education (Ferreiro-González et al., 2019). Research on use of escape room in education is still in an early phase (Taraldsen et al., 2020), and Veldkamp et al. (2020b) conclude that the teacher's application of escape room, with their complex sets of interrelations, and the desired outcome of implementing an educational game to help achieve desired learning outcome for the pupils, so far do not align.

The study presented in this article, is concentrated around 12 Norwegian teacher education students who participate in a mathematics course on problem-solving where the students are introduced to escape room as a possible didactic tool. Borasi and Finnegan (2010) and Van der Heijden et al. (2015) highlight the potential of teachers as change agents, and Taraldsen et al. (2020) identify this potential in the teacher education student's position as well, because teacher education students may bring new ideas to the schools where they have their teaching practice as students and to the schools where they eventually will work as teachers. One of such ideas is the use of escape room as a didactic tool in mathematics. According to the theories of Dewey (e.g. Dewey, 1916, 1938), reflection on active and passive experience may transfer into learning, which means that teacher education students in practice periods, and then as qualified teachers,

might bring new ideas, didactic tools, and possibilities into the school, based on what they learn during their teacher education. This is not just because they learn something specific about a didactic tool such as escape room, but also because, in general, they go through a significant kind of learning-based metamorphosis, from being an experienced pupil to becoming a new teacher, which may affect their beliefs about mathematics teaching and learning (e.g. Beijaard et al., 2000; Bishop, 2001; Philipp, 2007; Thompson, 1992), and therefore what priorities to make in their teaching. Beliefs seem to be in a dynamic interaction with knowledge, recognized by Bishop (2001) and Philipp (2007) as subjective knowledge. Beliefs are what one believes to be true. Subject to influence from feelings, beliefs become materialized through actions and are thereby visualized as values (Bishop, 2001). Van Zoest et al. (1994) reveal that teacher education students in general enter the teacher educational program with quite traditional, experience-based beliefs about teaching and learning priorities in school mathematics. Such beliefs may be seen in relation to experience as a pupil, for instance related to organization of mathematics lessons (Topphol, 2012) or norms in the mathematics classroom (Yackel & Rasmussen, 2002). Through their time at a teacher education program the students may be introduced to, and influenced by, approaches and opinions regarding mathematics teaching and learning that may challenge their beliefs, although this is not always the case (Amundsen & Haakstad, 2018). However, because of its well-documented novelty, the introduction to escape room, which serves as the foundation for this article, offered the participating teacher education students one such belief-influencing opportunity.

The identification of the need for attention to teachers' use of escape room (e.g. Veldkamp et al., 2020b), and the opportunity the introduction of such a didactic tool might offer regarding teacher education students' development as mathematics teachers and position as possible change agents for mathematics teaching in school, makes the objective of this study two-folded. The objectives are to understand the teacher education students' experiences of the use of escape room as a didactic tool in mathematics, and to gain insight on the impact of such an introduction on teacher education students' development as mathematics teachers. In order to approach these objectives this study intends to answer the following question: *How do teacher education students in a mathematics education course experience an introduction to use of escape room as a didactic tool?*

THEORETICAL FRAMEWORK

Game-based Learning

In educational research, facilitation for game-based learning (GBL) is recognized as an increasingly popular approach in school and teacher education (Plass et al., 2015; Moon et al., 2023). Salen and Zimmerman's (2004) definition of a game acts in this article as the foundation for

GBL in general and for the escape room: 'a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome' (p. 80). Plass et al. (2015) narrow the understanding of GBL down to a distinction between gamification and GBL. A gamification of content is, for instance, recognized by giving learners points or other types of credit for completing well-established activities (e.g. Lee & Lai, 2024). GBL replaces such an approach by redesigning the activities using artificial conflicts and rules of play to make them more engaging. The design of such activities relies on the balance between attention to content and the desire to play (e.g. Andriyani, 2023; Plass et al., 2015). On the one hand you want the participants to learn something, and on the other hand the only goal of play is for it to realize itself (Wilkinson, 2016). The context one enters with a playful purpose, together with goal and structure (Salen & Zimmerman, 2004), creates the GBL design.

According to Stolee (2021), there are four main categories of escape games: point and click, virtual reality, tabletop, and live-action escape games. Stolee (2021) claims that the live-action escape games offer the participants most tangibility and affordance conformity, which means that they best pave the way for activity, influence, reality, and affiliation. An escape room is a live-action escape game that, in short, offers the participants an artificial context where they are challenged as a group to make decisions, explore, find clues, and solve discovered problems to complete the mission within a given time frame (Nicholson & Cable, 2021). The escape room is built on the GBL design premises, where the goal of the contestants' learning through participating in the event is met by creating a play-based context in which the contestants immerse themselves to solve problems that are anchored in their curriculum.

In mathematics, the escape room setting may allow for emphasis on problem-solving in the mathematics classroom (Charlo, 2020). When applied in a school setting, the playful learning environment can be used to introduce the need for new subject content and skills (Andrews & Bagdasar, 2023; Borrego et al., 2017; Vergne et al., 2019). It can also be used to offer possibilities for repetition, deepening and transference of existing knowledge through application of well-known subject content and skills in new settings (de la Flor et al., 2020; López-Pernas et al., 2019). In addition, the participants in the escape room are made aware of the effects of their behavior on themselves and others (Lathwesen & Belova, 2021), through experienced need for communication, creativity, and cooperation (Peleg et al., 2019; Zhang et al., 2019; Veldkamp, 2022).

Because it is based on the definition of *game* (Salen & Zimmerman, 2004), being part of a learning community (Wenger, 1999) and learning through participation rather than through acquisition (Sfard, 1998) are important issues in GBL (Nicholson, 2018; Weines, 2021). The fundamental idea of GBL, however, is the opportunity to learn through the duality of experiences and challenges that the player encounters in the company of other players, and the complexity of this duality becomes visible in the wide range of reasoned attempts to associate various areas of influ-

ence on learning and learning outcome with GBL (e.g. Bober, 2010; Christopoulos et al., 2024; Plass et al., 2015; Weines, 2021), and thereby with an escape room in a school setting. Four major areas of influence stand out because of their overarching and fundamentally established position in educational research on learning: experience, self-regulation, social interaction, and motivation.

Experience, Self-regulation, Social interaction, and Motivation

Experience has been a focus of attention in educational research all the way back to Dewey's theory on learning (Dewey, 1916, 1938). For Dewey, experience includes a duality between active and passive. On the active side, the experience consists of trying out or exploring an activity, while on the passive side, the experience is the exposure to the consequences of the activity. In addition, experiences are influenced by the surroundings (one does something, and this action does something in return to the one who did something). According to Dewey, activity itself does not create learning, but learning takes place when the consequences of the activity are related to the activity. Hence, activities that are experienced to be without meaning do not facilitate learning. Such experiences are mere random impulses not transferred into learning because the passive side of experience is minimal. Dewey advocated that the value of knowledge depends on its use. Most of our experiences have phases of trial and consequence, or, in the words of Dewey, an active and a passive side. One does something, and when it fails, one does something else, and continues until something that works is found, and then that is used as a rule or starting point for new actions. One discovers and becomes aware of connections between one's actions and the consequences of them. Reflections about these actions and consequences provide learning and imply engagement and responsibility for future consequences of present actions (Dewey, 1916).

Dewey's theories about active and passive experience, and reflections about one's actions and their consequences are related to theories on *self-regulation* (Zimmerman & Schunk, 2001). Self-regulated learning includes the learner's goals, plans and self-motivational beliefs, experience of progress, and reflection on experiences in order to adapt learning strategies to adjusted goals, plans and beliefs (Zimmerman, 2000). Zimmerman (2000) divides self-regulation into a cyclic process consisting of three phases: forethought, performance or volitional control, and self-reflection. The first phase consists of the learner's conscious preparation for acting based on goals and plans for the up-coming action, influenced by the learner's self-motivational beliefs. The second phase is an action phase that contains the learner's active efforts influenced by volitional strategies, and is subject to self-observation of both personal effort and mimicking of observed skills. The third phase is a reflective, post-active process providing the learner with self-judgment and self-reaction that may influence adjustment of goals, plans and beliefs in a cycle-establishing revisiting of the first phase. In a learning community (Wenger, 1999), such as an escape room in a school setting, self-regulated learning takes place through an interactive process

between individuals and the environment they are in, a process that is operationalized by both Zimmerman and Dewey.

The principles of continuity and interaction are core in Dewey's theory of learning and show the relation between Dewey's and Zimmerman's pragmatic point of view and the influence of *social interaction* in GBL. The principle of continuity means that the present experience is based on previous experiences, and at the same time affects subsequent experiences. The previous experiences are crucial to how a situation or problem is understood and handled, and at the same time the experiences one makes in a new situation influence and shape one's understanding, interpretation, and attempt to solve future situations. The principle of interaction relates to the influence of interplay between one's previous experiences and the surrounding environment for experiences made in the present. Hence, the social dimension emphasized by both Dewey and Zimmerman highlights the importance of social interaction in GBL. This is identified by soft skills such as cooperation, confidence, communication, and critical thinking, and within these the application and development of features such as active listening, giving and receiving constructive correction, teaching of others, leadership, and trust in others through delegation of responsibility (Morell et al., 2020). Social interaction is a paramount feature within collaborative problem-solving that may trigger critical thinking skills (e.g. Khusna et al., 2024).

According to Pintrich (2003), *motivation* is often studied from four perspectives: the choice of activity, how the individual engages with an activity, persistence, and the outcome of actions. Facilitation of learning through an escape room that motivates pupils involves all four: expectation of relevance, eagerness to play and be strategic, ability to strive and endure, and future utility. From a Deweyan perspective, the pragmatic view is that the value of knowledge depends on its use, and therefore motivation is related to future usefulness, both in its strength and stimulation. Lack of activity, lack of interdisciplinarity and lack of cooperation work to alienate and inhibit motivation, according to Dewey (1938). In GBL research, however, the self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000a) is the prevailing motivation theory (e.g. Plass et al., 2015; Weines, 2021; Wilkinson, 2016). The self-determination theory is concerned with more than just the strength of motivation. It focuses on intrinsic or extrinsic motivation as stimulation for an activity, and the relationship between the two (Ryan & Deci, 2000b). In GBL, this relates to what motivation one has for involvement in a game experience, and how it will influence the game experience if one is intrinsically or extrinsically motivated to play and to obey the rules and structure of the game. As mentioned above, the playful purpose is one of the ingredients in a GBL design (Plass, et al., 2015; Salen & Zimmerman, 2004), whether it is intrinsically or extrinsically motivated; however, without motivation to become involved in the game, there is little chance of the game's purpose being realized. In a Deweyan perspective, the intrinsic motivation will be continuously influenced by the growth of extrinsic motivation arguments because of the increase in knowledge and skills through learning. This is also the case in a self-regulation perspective because of the increase in consciousness about one's own learning. However, one

does not stop being possibly intrinsically motivated, as evidenced by the willingness to play for the sake of the game and social interaction. Motivation is found in the balance between experience of challenge level and skill level related to the problem one faces, which aligns with Vygotsky's zone of proximal development (Nicholson, 2018; Ouariachi & Wim, 2020) and Wenger's learning community (1999). In an educational escape room setting, the operationality of how such processes are met is found in concepts such as problem-solving, exploring, play and creativity.

Didactic and Bildung

Didacticism is theory about teaching. In the classroom, the teacher's didactic stance reveals choices the teacher has made in the planning of the teaching and actions in the actual teaching situations. It also identifies both near and distant conditions for such choices. According to Klafki, the development of a didactic stance is based on bildung (Hohr, 2011). Bildung is an individual process that is continuously influenced through the individual's informal and formal knowledge- and skill-acquisition, and becomes an expression for the ability to make independent decisions (Korsgaard & Løvlie, 2003). This means that a person's bildung refers to the dynamic relation between the person's experiences and the personal and cultural development she encounters. Consistent with Dewey's principles of continuity and interaction, Klafki and Dewey seem to share the impression of learning and environment to act as conditions for the continuous development of character that is recognized as bildung (Straum, 2018). This makes bildung a process that continuously occurs in the meeting between a person's subjective prerequisites and experiences, and surroundings that are continuously culturally disseminated (Hohr, 2011).

The teacher education student enters the teacher education program with a bildung that consists of a personal identity and beliefs about mathematics teaching that are constantly confirmed or challenged by experiences made during the program. The teacher education student's identity as a mathematics teacher and beliefs about the didactics of mathematics are operationalized and challenged through the didactic choices she makes both in her own studying and in teaching practice during the teacher education program. Potential changes and refinement of such choices are related to both education and cultural development via didactic evaluations related to pedagogical processes (Arneberg, 2008; Torjussen, 2011). This means that the teacher education student's development of bildung as a mathematics teacher emerges through active experience of connections between what to learn and how to learn in mathematics and passive experience through evaluation of consequences for her didactic stance.

Klafki (1983) identifies two main categories of the concept bildung: material bildung and formal bildung. The first involves acquisition of attitudes, knowledge and values that have emerged through culture and society. Emphasis on material bildung may be expressed through a mathe-

matics teacher's prioritization of pupils' achievement of the national curriculum goals, as evidence of their acquisition of knowledge and skills in mathematics. Formal bildung involves developing inherent abilities and competences, and may be expressed through a mathematics teacher's prioritization of the learning environment ahead of scholar content. However, according to Klafki (1983), these two categories must not be seen as separate. This echoes Dewey's theory about learning: What to learn and how to learn are closely connected. There are no skills or methods detached from content (e.g. Toft, 2018). Klafki, as well as Dewey (Straum, 2018), suggests that such interweaving is required. On the one hand it offers an experience that opens up cultural content for the learner (here: it is possible to apply use of escape room to pave the way for learning in school mathematics). On the other hand the learner opens up for the cultural content (here: it is possible to emphasize various elements related to school mathematics through use of escape room). The result is that knowledge, skills, and experiences of a general (categorical) nature are created in the learner (Straum, 2018). The learner's awareness of this interweaving of content and form is what Klafki (1983) recognizes as categorical bildung. In this study, categorical game-based bildung emerges through the teacher education student's introduction to escape room. This includes examples that extend towards something bigger and more general (categorical) than simply what an escape room is, and the opportunities it provides for fundamental experiences that may motivate an alternative, fundamental way of thinking (here: application of a GBL design) in mathematics teaching and learning.

METHOD

Selection of Participants

In the beginning of 2021, 12 teacher education students were selected randomly (Brinkmann & Kvale, 2015), from a group of 44 students taking a 7.5 ECTS (European Credit Transfer and Accumulation System) mathematics education course on problem-solving. According to the European Commission (2015) 7.5 ECTS implies a workload of approximately 200 hours. Introduction to use of escape room in mathematics is part of this course, and therefore participation in the course was the sole selection criteria. The course was conducted in the sixth semester, and is part of the students' five-year teacher education program in Norway, where they qualify for teaching of mathematics in primary and lower secondary school. When commencing the course the 12 students had already passed 30 ECTS in mathematics education.

Description of the Introduction

The introduction consisted of three lessons that alternated between plenary lecturing and activities. Some sessions of group work were planned as part of the course, and the 12 teacher education students were divided into three groups. They were in these groups in all organized group activity during the teaching involving escape room introduction.

The first lesson (135 minutes) was devoted to the lecturer's introduction of escape room as a concept and a phenomenon. He gave escape room a definition, elaborated on different ways of designing escape rooms and previous research on the use of escape room for educational purposes, and suggested research-based indications about how this didactic tool seemed to provide opportunities in the teaching of mathematics that related to experience, self-regulation, social interaction, and motivation in mathematics. In addition, the students tried out an escape box (Veldkamp et al., 2020a). An escape box is based on the idea of players trying to break into a box instead of trying to break out of a room (Nicholson & Cable, 2021). The escape box was used as a step on the way towards a full escape room because of the lower level of complexity that an escape box entails, when all necessary information leading to a desired code is to be found on a box instead of scattered around in a room.

In the second lesson (45 minutes) the students were challenged to try out an escape room that had a content emphasis on mathematics. In groups the students were 'trapped in a cave', as shown in figure 1 below, where they had to solve five problems in order to escape.

Figure 1: Two student groups in escape room mode, 'trapped in separate caves'

The 'caves' were shaped by using walls, chairs and desks in the classroom. In each 'cave' there were different articles and puzzles leading the students in direction of problems containing both practical and cognitive challenges, and clues on how to combine all the answers, in order to

manage to escape the room. One of the problems was for instance written on a piece of paper hidden inside an empty bottle. In this situation the students first had to get the piece of paper out of the bottle without smashing it, and then crack the mathematical problem to be found. The problem they met was: *When writing the page numbers in a book, 3289 digits were used. How many pages were there in the book, when the first page of the book was labelled 1?*

The third lesson (90 minutes) started with a debrief session related to the experiences from the escape room tried out in the second lesson. In the debrief the students' ability to cooperate was emphasized, and strategies and solutions regarding the five problems were discussed. Towards the end of this lesson a plenary discussion about experiences with the introduction to escape room in mathematics was conducted. In this discussion the students elucidated on what possible use they found in escape room as a didactic tool in mathematics.

Collection of Data

Data were collected from the participants in the study through three stages. At the first stage they answered a small, qualitative survey. This was followed by a stage of observation. Finally semi-structured focus-group interviews were conducted.

Stage 1: Before they were introduced to escape room, the 12 students were informed about the project and their role in it, gave their consent, and then completed a small, qualitative survey. The purpose of the survey was to obtain the students' previous knowledge of escape room, expectations regarding the upcoming introduction, and their thoughts on teaching of mathematics.

Stage 2: I observed the three lessons, and filled in an observation form where it was described what happened in the situations and immediate understanding of students' active and passive experiences (Dewey, 1916, 1938). In the lessons, video recordings were used to collect data from the 12 participants during the group activities. The purpose of using observation was to obtain information about the interaction in the context being studied (Krumsvik, 2019), which on this occasion was the 12 teacher education students' meeting with an introduction to use of escape room in mathematics teaching and learning. The video recordings were watched immediately after each lesson and used to nuance the field notes. The video recordings offered opportunity to develop precise descriptions of the situation and accurate retelling of expressions the students had applied.

Stage 3: Two weeks after the introduction, the three focus-group interviews were conducted (interview A, interview B and interview C). Each student group was the same as the ones used during the introduction. The purpose of the interviews was to collect data from the participating students' sharing of opinions and discussions of their experiences about the use of escape room as a potential didactic tool in mathematics, and to use these data to investigate the meaning of what

the participants expressed, through describing, systematizing, and interpreting. The application of focus-group interviews was chosen because of the opportunity this data collection tool provides both for the participants' sharing of individual experiences and production of data in cooperation with other participants (Brinkmann & Kvale, 2015). I moderated all three interviews, using an interview guide with a semi-structured format influenced by the theoretical framework for the study and research on escape rooms, in addition to the preliminary impressions that were made based on the previously described survey and observations. Each group was asked about their expectations associated with the use of escape room, how they encountered the introduction in the mathematics course, and what thoughts they now had about the use of escape room as a didactic tool in mathematics. By using semi-structured focus-group interviews, it was possible to capture participants' individual and joint perceptions. In addition, the focus-group setting gave participants the opportunity to communicate with other group members, and through this to discuss, enlighten and elaborate on opinions and perceptions that emerged as a desired consequence of the focus-group structure (Brinkmann & Kvale, 2015).

Analysis

The analyses in this study are based on a hermeneutical approach (e.g. Gilje & Grimen, 1993). The analytic process started with a theory-driven identification of categories related to escape room in GBL, and on Dewey's theory of learning through experience. Four categories related to learning were identified: *experience, self-regulation, social interaction,* and *motivation*, each being registered in the data material through moments of recognition given by features and aspects identified through the elaboration of each category in the theoretical framework. This elaboration is based on argumentation found in well-established educational research specifically targeting each of these four categories. A directed content analysis (Hsieh & Shannon, 2005) of the survey and observations was used to establish analytic impressions of the participants' knowledge about and experience with escape room before the interviews took place. In accordance with Hsieh and Shannon (2005) a directed content analysis can be applied to identify, validate, and extend conceptually a theoretical framework by using existing theory and prior research as key concepts for initial coding categories.

In the next round of analysis, the same four categories *experience, self-regulation, social interaction,* and *motivation* were used to analyze the transcribed data from the three focus-group interviews to further investigate how teacher education students experience an introduction to use of escape room as a didactic tool in mathematics. This round of analysis consisted of multiple close readings and interpretations of the transcripts. This was followed by attention to text segments in the transcripts, a process that provided the study with selection of quotes to be used when presenting findings. The students are identified through the following labelling: AS1, AS2, AS3, AS4, BS1, BS2, BS3, BS4, CS1, CS2, CS3, CS4 in quotes from the three focus-group inter-

views. Utterances from the researcher is labelled R. The identification of findings also provided the opportunity to generate hypotheses and probable conclusions regarding possible impact on teacher education students' beliefs about mathematics teaching.

Trustworthiness

The trustworthiness of a qualitative research study will always be measured in relation to the validity and reliability of the study (Cresswell, 2014). In short, as a researcher, one must be aware that one's prejudices influence the research process, but still strive for transparency in the various phases of data collection and analysis. For instance, when gathering data from the observation, field notes were written, and it was made sure that they were structured in a way that allowed others to read and make sense of them. The field notes were read by the lecturer, who confirmed the registrations and impressions I had made. The dialogues from the video recordings and focus-group interviews were transcribed, and analyzed. Another researcher might make different interpretations and reach other findings because of the nature of influence from prejudices and preconceptions on interpretation of qualitative data (Gilje & Grimen, 1993). In this case, the lecturer who orchestrated all three lesson used for the introduction read through both the transcriptions from the interviews and my presentation of findings. He confirmed my interpretations and identification of quotes to support the findings. The lecturer is an associate professor in mathematics education. His credibility on this matter is founded on his broad background within mathematics education research and competence within qualitative research, his knowledge of introducing and using escape room in mathematics teaching and learning, and the fact that he was present in all three observed lessons.

The framework of the study has also been verified to strengthen the trustworthiness. In September 2020, a pilot study on the planning and data-collecting parts of the design was carried out. The survey, observation, and focus-group interview were piloted during the same course with the same lecturer but a different group of teacher education students. Minor, practical adjustments such as adding a head camera to each group during the group work were made after the pilot. In addition, the decision to use three groups, each with four students, was one of convenience because it allowed for the possibility of ruling out any insecurity related to the occasional absence of a student; data from two groups, each with three students, proved to give the study sufficient data. To sum up, it has been attempted to be as transparent as possible in the data collection and analyses, to provide replicable and valuable data that will provide trustworthy findings relevant to the research question. These findings are presented in the next section.

FINDINGS

The imperative of the findings section is to show, with support in quotes stemming from the interviews with the students, how the introduction to the use of escape room as a didactic tool in mathematics was experienced. The attention to findings is brought forward from a participant point of view and a teacher point of view, respectively. In extension of these findings, some considerations regarding impact on the students' bildung are made.

Participant Point of View

The students described the experienced introduction as something different from what they were familiar with in mathematics (conversations translated from Norwegian):

> BS2: It contrasts traditional teaching. You might be much more active here, physically.
> BS4: Yes. Mathematics is a subject where it is easy to become accustomed with a pattern of individual solving of tasks, with offering of plenary explanations of how to solve them if there are several pupils that do not understand what to do. But here…you solve problems, and do not just sit at your desk and calculate, calculate, calculate…
> R: So it has a physical dimension…because it invites movement?
> BS4: Yes, in a way.
> BS1: But also the inclusion of cooperation in mathematics. Normally, one is left alone to work on a task at one's desk, but in the escape room a group is supposed to reach solutions together, and that contrasts pretty much what we are used to in mathematics lessons.

In their further elaboration on such an impression, a typical mathematics lesson was described as follows: first, the teacher goes through a topic, then the pupils work individually with tasks, and finally the teacher shows the pupils how to solve a selection of those tasks. This is an impression that aligns with a traditional time signature for school mathematics lessons, identified by Topphol (2012). The introduction they experienced in relation to escape room, relied on participation-based experiences with problem-solving, exploring, play, and creativity with a didactical tool that they were somewhat unfamiliar with. AS1 commented, "Well, it was something new. We were like a group…it was an entirely different way of working, and we approached it in another way than, at least I, approach a regular mathematical task." The students argued that it was essential that they got the opportunity to try out escape room themselves. This refers to the active dimension of learning through experience (Dewey, 1916, 1938), and features related to group dynamics (Lathwesen & Belova, 2021) and social interactions (Morell et al., 2020).

The students emphasized their own participation in encountering both the escape box and the escape room that had mathematical content priority. When encouraged to elaborate further on their

experiences with the introduction, they first reflected on the organization and presentation of activities:

> R: You only had 20 minutes to work on the escape box, being the first encounter with an escape room session…
> BS1: Yes.
> R: How did you experience this encounter?
> BS1: It was fun to see how simple and down-to-earth you can present the escape room setting. Just use a box, with some tasks on it…and it instantly became apparent that we became excited and engaged.

It seemed to be a positive surprise that the escape box invited the participants so rapidly to become involved. Second, the students brought forward the problems they experienced as difficult to solve, basically because they struggled to reach solutions to them. This is an understandable attention, because of their need for solutions to all the problems, in order to escape the room, which to some extent also nourished the students' established opinion about the importance of product (here: solution):

> R: As part of the introduction lessons, [name of lecturer] also emphasized the debrief phase. What do you think about the debrief of the escape room?
> AS2: Very important.
> R: How come?
> AS2: To share both joys and frustrations…
> R: Mmm?
> AS2: Yes…in order to understand. At least on my behalf. I need to know how it is supposed to be solved, or else it may torment me for hours, days…you name it! Haha!
> R: So having the solutions to all the problems shared, so to speak…?
> AS2: Well, yes. For me it is annoying not to be enlightened about how to solve it. By having a debrief you get an impression of what the others did in the escape room as well, for instance if you split the group in pairs, and you did not catch hold of what the other pair was working on. Through a debrief I get to know what they were up to, instead of ending the escape room experience knowing only about the parts I was involved in, and thereby not being able to reflect on the holistic impression of the escape room because I do not know all the details. This has to be done in the debrief if it is not communicated while in the escape phase.
> R: Okay…so bringing attention to each of the problems met in the escape room is important in the debrief. Do you find other aspects relevant to pay attention to in a debrief?
> AS4: Yes, how to approach the room. We learned a lot about that from our first escape room try-out…What to look for, where to look, strategic use of the group. I remember that when we tried the room created for us, we did not even find all the problems. We whirled purpose-

> lessly around, so to speak, looking neither up or down. After that we have become more synchronized and strategic in our approach.

They pointed out the importance of using problem-solving strategies, solutions to problems, sharing of choices and experiences, and self-regulation based strategy development regarding the group's choices and activity in the room. The attention to product and process culminated in the students' support to the necessity of a debrief session, in accordance with research on use of escape room as a didactic tool (Sanchez & Plumettaz-Sieber, 2019). Later on in the interview AS2 also pointed out that it is easy to forget the problems if you are not given the opportunity to reflect on them afterwards. Through these reflections, Dewey's (1916, 1938) dimension of passive experience related to approaching problems in an escape room setting comes into display.

Furthermore, with relation to frames and settings for escape rooms, the students from a participator point of view discussed that the composition of a group seems important in an escape room, and that the setting can wipe out attention to time and place. Student CS2 explained that she felt confident being a member of the group she was assigned to (in the study). While referencing the escape room her group tried she stated, "The fact that you [the other three group members] were present made me feel that I cooperated, but I did the work all by myself without knowing." Hence, her confidence also enabled this student to be completely engrossed in her individual work with one of the problems in the escape room. She indulged in the playful feature of the escape room setting.

Teacher Point of View

The students acknowledged the balanced priorities between plenary lecturing and student participation in the lessons. These holistic reflections brought forward specific attention to escape room as a possible didactic tool in mathematics, from a teacher point of view:

> BS2: I find that it is, in a way, mathematics with an aim. Traditionally pupils work with tasks, but there is no aim to reach. In the escape room you have a clear aim. If one passionately indulge the room's context, then you have to solve the tasks in order to escape the room. That makes the mathematics lesson motivating, as opposed to a regular lesson.
> R: May such an alternative have some impact on the pupils' learning in mathematics?
> BS2: Well…yes, it might. Because you can use the escape room as a teaching method, and relate it to various practical contexts and problems…and reach conclusions on site. You can choose what context you want, like building a house, or whatever…you have to solve meaningful mathematical problems in a context that makes sense in the present.

BS2 experiences the escape room as a teaching method to possess a motivational dimension through focus on aim, instant need for resources one has as participant, and relation to a meaningful, practical context. This dimension was further exemplified through personal reflections on experiences from the specific escape room they had encountered themselves.

The students had various opinions about the necessity of presentation of a reliable setting as participants. One student (AS4) said that the story used did not catch his attention, while others (CS2 and CS4) argued that it was the playful approach given by the setting that gave meaning to the rules and motivation to solve the problems they encountered in the escape room. An example given by CS4 to underpin the latter opinion was that they were not allowed to use the internet on their mobile phones, as 'there was no coverage in the cave they were trapped in'. However, from a teacher point of view AS1 summarized the impression of possible influence of establishing a viable setting for the escape room experience:

> Well, we are grown-ups, but pretend that you are in primary school…Dim the lights, gather in a circle, have a narrative…right? Build it up…like, eeeh, once upon a time…the lights…people going back and forth…excitement about some issue that it is urgent to handle. At least I believe that the introduction to a setting has a great influence on the entering of the escape phase…at least it had for me!

Regarding the actual implementation the students mentioned the need for the escape room to be practically manageable for the teacher in the classroom, yet recognizable as an escape room for the pupils. This line of arguments was followed into the necessity of adapting the escape room to the pupils' age and maturity, but at the same time that children are used to role-playing and complying with the rules given for games. The argumentation therefore prolonged into emphasis on the importance of the possibility of learning through play, for instance through the following quote by CS2: "…I don't think they [pupils] know that play is cooperation, but it is a natural ingredient when they create a fictional world and play in it together."

The aspect of mathematical content was raised with reference to experience of the value of repetition of mathematical content:

> CS2: Yes, I also think it is a good way to use your knowledge… so that if you use it [escape room] as repetition, then you can apply the knowledge you have gained.
> R: Mmm.
> CS2: And see that you manage to use it.
> CS4: Mmm. Yes!
> CS2: That it in a way becomes beneficial.

CS2 saw a didactic possibility for use of an escape room in mathematics linked to repetition of mathematical knowledge, but then with support from CS4 extended into an argument for experi-

ence of usefulness of application of mathematical knowledge in a new situation. To sum up the impressions made from a teacher point of view the students claimed that what one already knows may be beneficial in the present, and not just be possibly beneficial in the future. In relation to this, the students argued for the importance of a teacher orchestrated debrief when the escape room session is finished, in order to share and reflect upon the pupils' experiences in the implementation phase, and establish connections to the learning objectives that the teacher had in mind while planning and developing the escape room.

Impact on Bildung

In an extension of the above findings, it is significant that the students saw both application possibilities in their own teaching practice, and experienced glimpses of impact regarding their beliefs about mathematics teaching and learning, and thereby their development of mathematics teacher identity. One student (AS4) concluded that he saw the opportunity and value for pupils to gradually be challenged to make escape rooms for other pupils, because of the possible impact on learning through creating:

> AS4: I believe that it is more learning in developing escape rooms than it is to experience them as participants…
> AS1: Mmm.
> AS4: …when it comes to learning of mathematics. Because you actually, when making something new, you have to use your knowledge, develop tasks, create the holistic setting, pilot the tasks…does this work? Is it necessary to make adjustments? This is quite different from being in an escape room as participant.

In another interview CS4 concluded, after some contemplation, "I believe that if we had not done it [the escape room] at the teacher education … then we probably would not use it when we start working as mathematics teachers either. [Because you] have not tried it … you know." The application of escape room becomes an active choice one makes as a mathematics teacher to possibly improve one's teaching for pupils' learning of mathematics. These two quotations support the impact of active and passive experiences on learning, through two students' identification of reflection on further use (AS4) and necessity of trying oneself (CS4). All in all, the introduction to escape room provided the teacher education students with experiences related to both a hands-on participant perspective and a more reflecting teacher perspective, for instance in an argument for application of escape room in teaching of mathematics and social studies:

> AS3: On my behalf, I have decided that escape room is something that I want to use in my teaching, and especially emphasize an interdisciplinary relation.
> R: Yes?

AS3: For instance, since I have specialized in mathematics and social studies in my teacher education, I see opportunities to intertwine knowledge-based attention to tasks and problems from these subjects with for instance priority to development of competence in cooperative work.

Such experiences may indicate an impact on the participating students' beliefs about mathematics teaching and learning, because of their willingness to change. However, the possible impact on their bildung is hidden, both for me as a researcher and for them. Hence, only hypotheses can be generated regarding bildung and the teacher education students' possible change agent influence stemming from the upcoming discussion of the findings related to the students' experience with the introduction to escape room, followed by conclusions that can only be probable.

Summary of Findings

To sum up, the findings show that traces of a traditional perspective on teaching and learning of mathematics are clear among the students, for instance through their description of a typical mathematics lesson and their stated importance of sharing the solutions or answers to the problems on the escape box and in the escape room in debrief sessions. The students compared new input regarding teaching and learning of mathematics with their established beliefs about mathematics, but revealed glimpses of willingness and curiosity to change perspective, after being introduced to use of escape room as a didactic tool in mathematics.

DISCUSSION

Through the introduction to escape room as a didactic tool in school mathematics, teacher education students were given an opportunity to experience an approach to problem-solving in mathematics that challenges the didactic of the traditional mathematics classroom (Van Zoest et al., 1994; Topphol, 2012). The above findings describe the introduction as a somewhat surprising alternative to the 12 teacher education students' expectations for the mathematics classroom. The findings, however, show that the students are open for change of perspective, after being introduced to a GBL alternative that calls for a change of beliefs about teaching and learning of mathematics from a traditional, acquisition-based individual learning perspective to a more participation-based learning community perspective (Sfard, 1998; Wenger, 1999). The students appreciated that escape room was introduced in a well-grounded manner, and that they had the opportunity to try out both an escape box and an escape room. This appreciation is shown first through clear interest and arguments regarding organizing, adaptation to pupils and emphasis on variety to positively influence motivation. Second, the students seemed to experience escape room as a means of offering pupils a collective context for repetition of mathematical knowledge and skills

through application in a new situation while experiencing the benefits of mathematical competence and social interaction in the present.

According to Dewey (1916; 1938), learning and experience are intertwined. One makes experiences when one creates new balance through activity and consequences of the activity where there previously was imbalance. At the same time, Dewey is concerned about the value of the experiences and the direction in which the experiences orientate the learner. The intentions of, for instance, the Norwegian curriculum for compulsory schooling imply that pupils should have experiences that are not limited to cognitive knowledge and skills, but have a broader, educational perspective (Kunnskapsdepartementet, 2017). Within GBL experience, self-regulation, social interaction and motivation are key areas in such a perspective, and the findings show that the students seem aware of the opportunity to use escape room to adapt learning strategies to task requirements (Zimmerman, 2000), to emphasize group dynamics (Peleg et al., 2019; Zhang et al., 2019; Lathwesen & Belova, 2021; Veldkamp, 2022), and to generate motivation (Ryan & Deci, 2000b) regarding both subject matter content and development of 21st century skills (Andrews & Bagdasar, 2023; Kunnskapsdepartementet, 2014; Morell et al., 2020). If so, this means that the playful foundation of GBL, a socio-cultural approach to learning (Ouariachi & Wim, 2020; Plass et al., 2015; Weines, 2021), and the acknowledgment of creative processes such as problem-solving together suggest that an important objective is to go beyond subject matter content and give priority to the learning process (Charlo, 2020). To succeed in paving the way for such a learning objective the teacher must see the pupil, and not merely the subject and its content. Such a perception does indeed both depend on the teacher, and influence the teacher.

The possible change of the participating teacher education students' beliefs about mathematics teaching and learning, in this particular case, surfaces through their experience with escape room as a didactic tool that represents a change that the teacher education students seem to find interesting. The main purpose of teacher education is to educate quality teachers, that is, teachers who, in addition to scholar knowledge, know how to pave the way for pupils' learning, or apply a well-founded didactic approach. Requests for changes in the educational sector are based on societal development, educational research, technological revolutions, and education policy reforms (European Schoolnet, 2018; OECD, 2019), and therefore teacher education students have to learn how to relate to such requests for change through development of their own didactic stance, operationalized through their teaching and continuous answering of the questions of what you learn, and how you learn. One can relate to new active and passive experiences with reflection that leads to deliberate change of practice (Dewey, 1916). The opposite to adaptation and embracing of changes and development is the routine, where the possibility of change is measured in relation to what is established, and then rejected. The experienced introduction to escape room seems to offer an alternative to the traditional social and psychological norms of the mathematics classroom (Yackel & Rasmussen, 2002) through GBL's emphasis on experience, self-regulation, social interaction, and motivation.

The learner's bildung is influenced through the meeting between object and subject, and stems from her learning based on personal judgment of the value of content, form, and relations between these. Through didactic choices for the teaching and learning environment, the teacher paves the way for experiencing such meetings. With reference to Klafki's (1983) categorical bildung, this means that if the teacher education student meets a well-founded introduction to a new didactic approach in mathematics teaching (here: use of escape room in school mathematics), and this meeting awakes interest in and awareness about the interaction between what an escape room is, how it represents learning possibilities in mathematics, and why the escape room approach is emphasized because of mathematical content one can learn, then a categorical bildung process is recognizable. When the teacher's didactic choices for this meeting are based on a balance between attention to content and the desire to play, and thereby based on the fundamental idea of GBL as an opportunity to learn through a duality of experiences and challenges encountered in the company of other players, a basis for categorical GBL bildung may be recognizable. Such a basis may provide an environment for possible change in the participating teacher education students' beliefs about mathematics teaching and learning and their identities as mathematics teachers, that is prosperous from a Klafkian and Deweyan perspective. This might support the teacher education students in becoming future change agents for the use of escape room as one of several didactic tools in mathematics at the schools where they will be working as mathematics teachers.

CONCLUSION

The findings in this study show that use of escape room in mathematics teaching was met from a traditional perspective on teaching and learning of mathematics in school. However, the findings also implied glimpses of willingness and curiosity about the idea of trying out this new, game-based, didactic tool. The introduction offered them opportunities for both active and passive experiences, and to reflect on teaching and learning of mathematics based on application of a new didactic tool. This may have made a difference when it comes to the intrinsic impact on the students' beliefs and thereby bildung as mathematics teachers. One of the students (CS4) stated that without the well-founded introduction to escape room she experienced, she would have been unlikely to try out escape room as an activity in her own teaching practice. By bringing escape rooms into mathematics teaching in school, the teacher education student may be recognized as a mathematics teaching change agent, but such an initiative will only stem from an inner conviction about the value of making such a didactic choice, related to one's didactic stance.

The students' participation in this study have made it possible to display valuable contributions to the field of mathematics education. Collection of data regarding the teacher education students' introduction to the use of escape room as a didactic tool in mathematics, has made it possible to give empirical support to theoretical frameworks that investigate what constitutes GBL

in mathematics. Through emphasis on the pivotal role of the teacher in planning, conducting, and debriefing of an escape room experience in mathematics, this study also contributes to the growing body of knowledge about GBL in mathematics and more specifically about how escape room may work as a beneficial and meaningful part of mathematics learning in the classroom.

It is necessary to highlight that this is a qualitative study where only 12 teacher education students participated. This may open for theoretical generalization due to experiences other teachers and researchers have with use of escape room in education. Selection of other students from the group of 44 would have provided the study with other data (Brinkmann & Kvale, 2015). However, due to the equal conditions in the introduction of escape room in mathematics, I assume that such data would provide me with more or less the same foundation for analyses. Another possible limitation is the traditional perspective on mathematics teaching and learning held by the students in the study. This is not necessarily the prevailing perspective among teacher education students in mathematics neither in Norway, nor in other countries. A third limitation might be choices made for the actual introduction, for instance the design of the escape room and choice of mathematical problems. In reply to such limitations, the use of a GBL-based framework has provided the study with a methodological approach to identify and understand teacher education students' reactions and responses to an introduction to use of escape room as a didactic tool in mathematics. This offers a useful alternative for other researchers who are curious about use of escape room in mathematics, for instance in relation to frontiers such as learning outcomes, cross-sectional collaboration in both development and application of escape rooms in education, and use of digital escape rooms. I am aware that this study is limited to investigate a selection of teacher education students' experiences with an introduction to escape room in mathematics. Therefore additional research on teacher education students' use of escape room as a didactic tool in practice periods, or as new teachers in primary and lower secondary school teaching, is needed to form an impression of their position as possible change agents when applying an escape room based on the didactic questions of what you learn and how you learn.

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