



Towards Computational Play

Designing Open-Ended Play-Responsive Environments Supporting Computational Thinking in Early Childhood Education and Care

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Abstract. Computational play is a novel concept and scarcely researched indicating that there is a need for moving beyond deficient models of Computational Thinking (CT) to more robust knowledge by integrating overlooked needs and interests of children and thus engaging them more substantially in computational play on their own premises. However, outcomes from the authors' previous studies on digital and computational play in Early Childhood Education and Care (ECEC) in a Nordic context demonstrate that digital technology has the potential to reconfigure play activities supporting children's computational play. Based on a participatory design approach using workshops as a method, the study seeks answers to how play can be used as a pedagogical tool to promote children's computational explorations, and also the other way around, how computational exploration can inspire and enrich children's play in ECEC. The aim of the workshop activity is to build a dialogue between researchers, ECEC children and their teachers to integrate computational play into mathematics in ECEC practices. The study will contribute to how an open-ended play-responsive approach to computational play can promote children's conceptual understanding and how it can be facilitated. The expected outcomes will extend the knowledge of computational play in ECEC practices by incorporating identified good practices and guidelines.

Keywords: Computational Play · Early Childhood Education and Care · Open-Ended Play-Responsive Environments · Participatory Design · Workshops

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the end of the Engage phase, students will have prepared a clear challenge brief which can have a significant impact on engagement (Rådberg, 2020), as it provides them with a sound understanding of what they are expected to accomplish and why it is important, creating a sense of purpose and direction, which can be a powerful motivator for students to embark in the subsequent research-led (Investigate) and hands-on (Act) phases.

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Table 1. A T&L blueprint for the Engage phase.

	1	2	3
Components	The Big Idea: A central concept or theme that is important on a global scale. An abstract call to action	Essential Question(s): Open-ended, thought-provoking question(s) that identify(ies) what is important to know about the big idea	The Challenge: Actionable, relatable, and relevant to students' lives and communities; should be something that they are passionate about
Learning Rubrics	Develop a deeper understanding of the matter and a sense of what is globally important	Use existing knowledge and own's opinion in a new context to identify areas of interest in critical and creative ways	Decision-making based on personal aspirations and perception of impact
Example	Energy	How aware are members of my community of their energy consumption? How is energy being sourced to in my community? ...	Increase awareness toward energy sustainability in my local community
T&L Activities	Definition of Purpose	Forecasting / Backcasting	Sorting the Anticipated Impact
Tools	 The Impact Plan		
Engage Expected Results	Self-awareness and self-positioning towards pressing concerns and needs	Commitment with The Big Idea through personal and mutual meaningful connections	Ownership and excitement through the selection of a compelling challenge

The proposed T&L blueprint, which will be first implemented and assessed in the context of CDW at the University of Aveiro, is a way of ensuring the Engage phase can be thoroughly used to maximise the motivational benefits from the beginning, so that students are cognitively and emotionally engaged with the selected challenge. It maintains and augments all the advantages of CBL in its entirety and DT's leverage and convenience in T&L practice. As opposed to common practice—where students reflect on the impact of their actions by reviewing them—in this proposal they do so during the Engage phase, by previewing answers to prompts/stimuli that are guided by the underpinning questions “Why is this important to me and to the world?” and “Who is the challenge going to impact?”. They complete these anticipation exercises juggling between individual reflection and collaboration with their team members. Hence, toward

personally relevant? The idea is, on one hand, to make sure the Engage phase is fully experienced, namely by making students identify their WHYs in regard to the Big Idea; on the other hand, DT should remain as the main operative system, for which reason the void during the Engage phase would follow the framework proposed by Lelis (2022:54) which extends the Double Diamond by suggesting that most design processes (those leading to innovation) go through a stage called Determine, since individuals find their place in the world by 1) questioning the *status quo*, and 2) foreseeing the impact they can make, thus *determining* the one challenge with increased *determination* (Fig. 3).

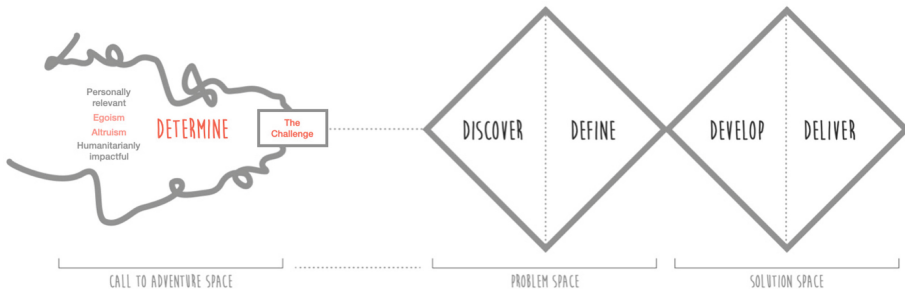


Fig. 3. The Determine stage (adapted from Lelis, 2022).

Hence, a T&L blueprint has been devised so to guarantee engagement since very early stages and to ensure the Engage phase is no longer ignored (Table 1). The Impact Plan (Lelis, 2022; 2021) will be used throughout the Engage phase to aid on the identification of an actionable, meaningful and engaging challenge, by guiding students on the respective teaching and learning activities.

The Impact Plan includes a toolkit that is meant to help individuals anticipate the impact of any projects or activities they may need to commit to. It starts by guiding them on the definition of their purpose, moving on to a few speculative exercises, followed by the actual anticipation of possible impact of whatever projects/activities, grounded on a deck of cards containing stimuli and prompts that reinforce the questioning and tentative answering regarding different contexts of impact: 1) Continuous Learning and 2) Career (both self-centred), 3) and the three pillars of sustainability (Economic, Environment and Social, which are planet and humanity-led).

The expected engagement-related results are an increased sense of self-awareness and self-positioning (building up students' personal identity) towards the current and pressing matters and the global needs that are proposed as Big Ideas. Additionally, it is expected the development of a certain level of commitment with the Big Idea (and its nuances) through personal/mutual meaningful connections. Through inquiry-based exercises, students will be able to foresee how whatever arises from the Big Idea will impact their wellbeing, the achievement of the established learning outcomes, and the competences they need to develop to pursue their ambitioned careers. Finally, students are expected to be excited authorities in the decision-making toward the selection of a compelling challenge.

project should start with the identification of its WHY, for inspiration and purpose. Only then one can decide HOW to do it, and from there, arrive at the WHAT. This is why we realised the CBL approach that has been implemented within our T&L practice for the past two years had been skewed: 1) students were hardly having any contact with the first CBL phase (Engage) which does not seem to align to any of the DT stages, and 2) they were skipping the initial DT stages in the hurry of starting their mid-fidelity prototypes. It has been observed that the thought process around answering WHY—e.g. *Why is this Big Idea important to me?*, *Why is it urgent to solve its attached problems?* and *Why do I want to be part of the solution?*—was completely insipient (Fig. 2). Before beginning a project, students should identify the challenge they will be addressing, and develop a clear understanding of the problem they will try to solve. Investigate (aligned to HOW) is a phase that involves ethnographic and exploratory work to both understand the people involved/affected. Many of our students tend to shorten it so they can move on to Act (aligned to WHAT) as they get to see the concreteness of their possible solutions.

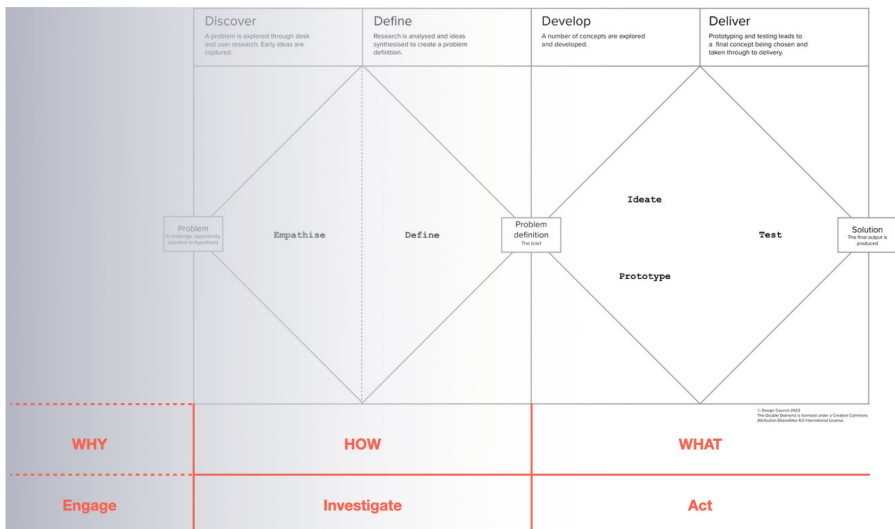


Fig. 2. The misalignment between DT and CBL frameworks

4 A Proposal for Increasing Engagement Since the Engage Phase

It was clear to the teaching team that guidance would be needed to support students in considering existing assumptions and acknowledging conscious and unconscious biases that may hinder (or otherwise) the way they foresee the future. By departing from a position in which students will be designing not just for the others (altruism) but for them as well (egoism), the aim is to explore and develop an increased sense of purpose, so to answer the question that is ideally expected to be resolved by the end of the Engage phase: *How can students identify a challenge that is both humanitarially impactful and*

When preparing students for the UI/UX industry, conducting them through opportunity recognition (Grau and Rockett, 2022) and the design of positive user experiences is pivotal. This is why Design Thinking (DT), a process model that is widely used within the UX/UI sector, has been the structuring T&L method of CDW. Although there are about 15 DT different models (Kueh and Thom, 2018), two of them are most popular in this area of specialism: the Stanford d.school's, which promotes the iterative stages *Empathise*, *Define*, *Ideate*, *Prototype*, and *Test* (d.school, n.d.), and the Design Council's Double Diamond framework, which explains the process of working in design, after steps *Discover* and *Define*—dedicated to the Problem—and steps *Develop* and *Deliver*—dedicated to the Solution (Design Council, 2019). Roughly, *Empathise* coincides with *Discover*, *Define* corresponds to *Define*, *Ideate* and *Prototype* align with *Develop*, and *Test* aligns with *Deliver* (Fig. 1).

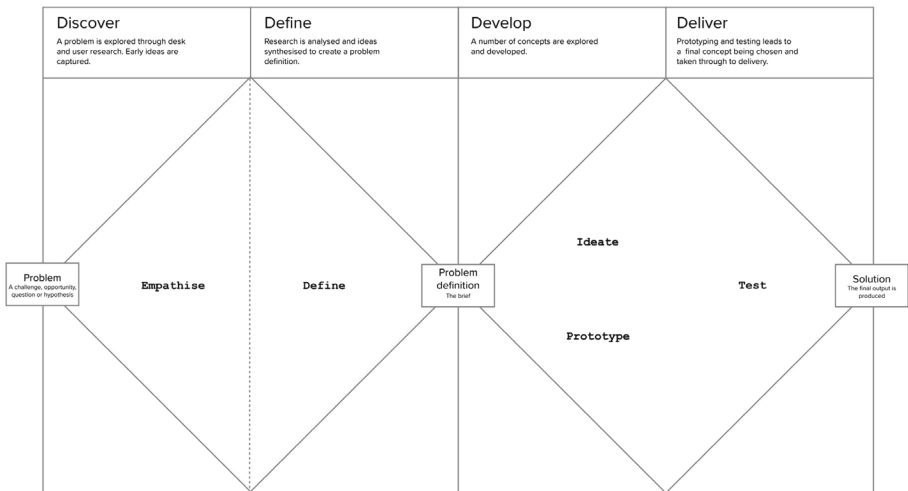


Fig. 1. The Double Diamond aligned with Stanford d.school's DT five stages (adapted from The Design Council, 2023)

3.1 Acknowledging the Issue of Giving Engage the *Cold Shoulder*

CDW's first taught sessions are dedicated to the initial thinking around the project students are expected to commit to. Yet, many students overlook the importance of questioning the problem and the existing predefined conceptualisations. The observed tendency is to rapidly move on into prototyping possible solutions, most of them weakly underpinned by sustained or validated information (Loranger, 2014). This is because students' engagement tends to increase when they face practical activities that move them away from the abstract content that is common at the beginning of a project (Samah *et al.*, 2022; Rodriguez-Calero *et al.*, 2020). In fact, they seem to concentrate most of their attention on the WHAT of their chosen challenge, little on the HOW and nothing on the WHY, precisely the opposite of what Simon Sinek (2009) proposes: that any

enjoyable they are more likely to experience positive emotions such as joy, excitement, and contentment which, in turn, lead to greater happiness.

In the context of higher education, CBL easily keeps students engaged with the learning process, since they deal with real-world issues. According to Johnson *et al.* (2009), this type of active learning can be particularly motivating for students, since it is designed to be interdisciplinary and project-based, allowing students to understand the context, see the relevance of their education, and foresee the impact they can have on the world. For Rådberg *et al.* (2020), CBL allows students to anticipate the impact of their projects by engaging in a process of foresight, which involves exploring and anticipating the potential consequences of their actions. It also prepares students for the workforce by developing skills such as critical thinking, problem-solving, collaboration, and communication (Shuptrine, 2013; Johnson *et al.*, 2009). Hence, engagement is a key goal of CBL, due to its significant effect on a student's wellbeing and achievement of predefined learning outcomes, but also on the potentially increased success toward finding a plausible and impactful solution.

2.1 CBL's Engage Phase

This is particularly true within the Engage phase, the first in the Challenge-Based Learning framework. Students move from an abstract Big Idea (which is a call to action) to a concrete, actionable and relatable Challenge, using the Essential Questioning process (Nichols *et al.*, 2016). This phase's goal is to personally connect students to the subject matter through the identification, commitment, and ownership of a challenge, helping them in developing a clear understanding of the problem they will be trying to solve.

According to Apple's guide (2008) and Nichols *et al.* (2016), the Engage phase consists of three steps: 1) the definition of a Big Idea, which is a central topic that is important on a global scale; 2) the formulation of Essential Question(s), which can be more than one and which are expected to reveal that students can identify what needs to be known about the Big Idea; and 3) the identification of one challenge that the students can relate to and foresee the meaningfulness of resolving the problems associated with it. Each of these steps can be assessed through the following rubrics, respectively: 1) develop a deeper understanding of the matter and a sense of what is globally important, 2) use existing knowledge and own's opinion in a new context to identify areas of interest in critical and creative ways, and 3) make decisions based on personal aspirations and perception of impact.

3 The Teaching and Learning Context Under Scrutiny

For the last two years, and since the validation of MA in Web Communications & Technologies at the University of Aveiro, Portugal, the taught and first year of studies runs under CBL. The Big Idea is defined in collaboration with external entities that have been playing the role of *partners*. The Engage phase is aligned with the first weeks of semester 1 modules, being "Communication Design for the Web" (CDW) one of them. Despite the generic CBL approach implemented across the MA course, each module is expected to define its own specific T&L methodology and assessment strategy.

According to Nichols *et al.* (2016), in a CBL approach students work through a three-phase framework that involves 1) identifying a compelling challenge within a certain community and from a given Big Idea (Engage stage), 2) developing a plan to address the challenge (Investigate stage), and 3) implementing the plan to make a difference in the community (Act stage). The authors argue that successful CBL is grounded on providing students with structure, support, checkpoints, and the right tools, while allowing space for self-directed, creative, and inspired learning. In fact, CBL can be highly motivating for students who, whilst engaged, are more likely to think deeply about the content, and to construct an understanding that entails integration and application of the key ideas. However, engagement may initially drop if the activity brief is unclear, or if the challenge is perceived to be far beyond the students' competences. This is why it is important that students become more comfortable with the challenge, so the learning process, the probable outcomes, and the impact that a possible solution may entail can serve as polestars.

One way of promoting engagement and motivation is through foreseeing the impact of a project, since it can help students develop a sense of purpose and meaning (Rådberg *et al.*, 2020). However, the literature on CBL tends to suggest this is ought to be done by planning, setting goals and doing research (Johnson *et al.*, 2009), which typically takes place during the Investigate phase, or through reflection tools (Khambari, 2019; Shuptrine, 2013), which tend to be implemented throughout or even after the Act stage. The literature on how CBL engages students by making them anticipate the impact of a project (since the Engage phase) is very scarce, not to say inexistent. It is important that students are given the structure and guidance so they can quickly empathise with the Big Idea, define a problem associated to it, and identify a purpose that will sustain the creation of a stronger bond toward the activity.

2 Engagement in CBL

Several authors state that engagement refers to the level of involvement and enthusiasm that students have towards learning tasks and learning success (Richards, 2023; Leijon *et al.*, 2022; Saroyan, 2022; Shuptrine, 2013; Johnson *et al.*, 2009). When students are engaged in their learning by pursuing activities that are personally relevant (Shuptrine, 2013), they are more likely to be motivated, focused, and committed to their education which, in turn, leads to increased effort and better academic outcomes (i.e., higher marks, increased retention, and improved performance) (Nichols *et al.*, 2016; Apple, 2008). For Johnson *et al.* (2009) the learning process will be more actively engaging when students ask questions, draw connections, and use what they have learned in novel contexts. Sarrantia *et al.* (2022) observed that engaged learners display positive emotions, cognitive effort, and attitudes of enthusiasm, confidence, participation, and active involvement. When individuals are engaged in an activity, they are more likely to feel a sense of confidence in their ability to make decisions related to that activity. The way decision-making happens becomes also more rapid and systematic (Nichols *et al.*, 2016), which is particularly important in situations where individuals are faced with uncertainty or ambiguity. Moreover, according to Escobar-Tello (2016), engagement is closely related to happiness: when individuals are engaged in activities that they find meaningful, rewarding, and



A Teaching and Learning Blueprint for Increasing Engagement in Challenge-Based Learning

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Abstract. Challenge-Based Learning is an active learning approach that involves students in identifying and addressing real-world problems. It follows a three-phase framework that includes the Engage, Investigate and Act stages. However, despite its name, and due to its naturally initial fuzziness, during the Engage phase engagement is low compared to the other two phases, namely when the challenge is perceived to be far beyond the students' competences. This is why it is important that students become more comfortable with the challenge and develop a sense of ownership over it. This paper aims at presenting a teaching and learning blueprint for increasing engagement in CBL's phase Engage, by guiding students on the identification of a purpose, helping them anticipate the impact of their potential solutions on the community and the world, which can motivate them to engage more deeply with the challenge. It also suggests that progress can be assessed during this phase through rubrics aligned with its three defining moments. Finally, it discusses the teaching and learning context in which the proposed blueprint will be implemented: a Portuguese masters course on Web Communication and Technologies, where the Big Idea is defined in collaboration with external entities, and where design thinking is the main method.

Keywords: Challenge-Based Learning · Student Engagement · Design Thinking · Double Diamond · Anticipation of Impact · Purpose

1 Introduction

Challenge-based learning (CBL) is an experiential inquiry-based framework to teaching and learning (T&L) that encourages groups of students to solve real-world problems by identifying, analysing, and designing a solution to a local or global challenge, while acquiring content knowledge in various subjects (Rådberg *et al.*, 2020; Nichols *et al.*, 2016). Students are supposed to work with multiple stakeholders, asking relevant questions, developing deeper subject and context-related knowledge, accepting, and solving challenges, and finally sharing their experience. It was initially proposed by Apple Inc. in 2008 as a T&L strategy for the American high school system to meet the needs of the 21st century workplace, but it has since moved into the higher education sector across the world (Leijon *et al.*, 2022; Chanin *et al.*, 2018; Johnson *et al.*, 2009).

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The expected outcomes of this study will incorporate identified good practices and design guidelines. Thus, the study will contribute to seeking answer to how cross-disciplinary novice design teams by means of prototyping can release problem-solving capacity based on their practical experiences and needs.

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research practice, including requirements for confidentiality, consent, information, and autonomy.

Before collecting data, we provided information about the study and the planned collaborative research, the responsibilities of the researchers concerning the data protection act, anonymization of data, storage of data and the participants' right to withdraw from the research at any time. In this paper, the data have thus been anonymized and stripped of any identifying details. Verbatim sequences quoting from interviews have been carefully edited to avoid identification.

4.5 Analytical Approach

The analysis of the gathered data is in the pipeline and thus not included in this work-in-progress paper. For the analysis, we will use a thematic approach adopting Braun and Clarke's analytical phases [54] (see Table 3).

Table 3. Overview of the analysis process [54].

Phase	Description of the analysis process
Getting to know the data	Watching and re-watching the video data and observer notes
Generating initial codes	Systematically coding interesting features of the data and gathering data relevant to each code
Searching for initial themes	Synthesizing codes into initial themes and gathering relevant data to each initial theme
Reviewing themes	Checking if the themes work in relation to the coded data and the whole data set, generating a thematic map of the analysis
Defining themes	Iteration of the analysis to refine the details of each theme in relation to the research question, generating definitions and names for each final theme

5 Expected Outcomes

The next step of thematic data analysis will extend the knowledge of novice design teams' capabilities to solve design problems by means of focused problem framing, visualization, and experimentation. Thus, the study will contribute to unfolding how participants from local practices can ensure effective collaboration to cope with emerging dilemmas. In addition, the study will contribute to specifying how a clear problem framing can provide direction for novice design teams to collaborate across stakeholder disciplines to handle complex issues. Also, the study will expose the kind of tools and approaches that productively can be used in problem framing, visualization, and experimentation processes where novice design teams are included.

Table 2. Overview of the design phases included in the study.

Design phases	Focus of the design phases
Problem framing	This phase focuses on clarifying the issues, where the empirical data generated from the contact with the participants is worked through to frame the design task. This is a key activity and is carried out before focusing on problem-solving
Ideation	The goal of this phase is to develop ideas targeting a number of solutions to the problem that has been framed in the previous phase
Prototyping	This phase focuses on creating a prototype, based on the outcomes from the previous ideation phase, i.e., to create a tangible design that can be analyzed by the participants
Testing the design	This phase has a focus on giving the participants the opportunity to reflect upon and give feedback to the prototype. This, in turn, opens for another empathizing process together with the participants to learn about their needs and wishes for the design

Each design phase was carried out in three iterations.

4.3 Methods

To answer the research question regarding the ways problem framing, visualization and experimentation elements were used in the DT process of the novice design team, we used focus groups and ethnographic participant observation as methods for the empirical generation of data. Focus groups can generate complex data at group level and were thus relevant to use in the present study as the DT processes included a variation of interpretations and understandings of the DT activities. Hence, the design team could challenge and complement each other’s interpretations based on their contextual pre-understanding [51]. Halkier [51] identifies three models of focus groups: (1) a loose model, (2) a tight model, and (3) a funnel model. In this study, we applied a loose model to the focus groups, where only a few guiding questions were prepared in advance to leave space for the design team to take control of the direction of the discussion. We carried out six focus groups, two in each of the three design iterations. The purpose of the focus groups was to identify how the participants, considered as design novices, by means of prototyping, could frame, and reframe the problem at hand.

In addition to focus group interviews, we used the participant observation method [52]. The purpose of these observations was to observe the participants’ interaction when framing the problem at hand, ideating, developing, and testing the prototypes.

This section on methods will be further developed in the next step, where for example the procedures of each of the methods will be further elaborated.

4.4 Ethics

The study followed the personal data acts in Denmark (502/2018) addressing handling, archiving and publication of data generated by research. This is in accordance with the General Data Protection Regulations (GDPR) [53] and ethical guidelines for good

months. Another potential disadvantage of the participant selection is that they are part of the SICWT network and thus assumed to be a reasonably homogeneous group. Halkier [51] emphasizes that there may be a risk that the interactions will not be diverse enough with a homogeneous group, but that it may make it easier for the participants to relate to each other. Since this study targets insight into the design of a particular part of the platform (the registration roadmap) within a specific context, a homogeneous group representing a joint interest is thus considered as a strength. Table 1 presents an overview of the participants and companies involved in the study. Each one of the three companies was represented by one participant in each of the three design iterations. The companies, the SICWT cluster, as well as the participants are anonymised. The participants from the SICWT cluster vary, while the selected companies are consistent.

Table 1. Overview of the participants in the study.

Design iteration	Individual participants	Company
First iteration	Participant FE	Company 1
	Participant LN	Company 2
	Participant LB	Company 3
	Participant TC	SICWT
	Participant M	SICWT
Second iteration	Participant FE	Company 1
	Participant LN	Company 2
	Participant LB	Company 3
Third iteration	Participant FE	Company 1
	Participant LN	Company 2
	Participant LB	Company 3
	Participant BB	SICWT

4.2 Procedure

The participants were part of a design thinking (DT) process divided into four iterative phases: (1) Problem framing, (2) Ideation, (3) Prototyping, and (4) Testing the design [9, 33]. The focus of each phase is described in the below, Table 2. The study included five participants from three healthcare-oriented companies and from the science cluster. The design task included in the present paper was to develop a web-based interface (roadmap) for a digital platform that systematically can assist its users to register a product idea within the welfare technology sector and be connected to other stakeholders that have an interest in developing a similar kind of health promoting idea.

way, the present study involved prototyping activities for the participants to share an understanding of the design ideas.

The theoretical framework is at the moment a work in progress and will be further developed in a next step. The theories on DT, co-creation and prototyping will be elaborated by, for example critically positioning the topics and, based on the soon to be finished data analysis, identify core and relevant analytical concepts.

4 Methodology

The study is based on a co-creation methodology [48] including a DT process divided into four phases (see Table 2). The co-creation procedure is an iterative and structured process, including different methods and techniques. One of them is prototyping, which is a valuable strategy to enable participants to visualize their thoughts, experiment with potential solutions, and suggest improvements to enhance a solution [48;49].

The iterative, cyclic, process, was a crucial ingredient in the present study and included features such as collaborative idea generation, reflection, and evaluation of ideas, and finally a refining process. These aspects were important to the participants' motivation and learning along with the iterative process [9]. The process was not linear but based on repetition, where each repetition (or iteration) was used as a starting point for the next one. The starting point was in other words a way to frame or reformulate the specific problem and thus constituted a direction for the iteration [11]. It was the project leader who had this kind of 'steering the boat' role, i.e., pointing towards a clear direction for the co-creation process.

4.1 Context of the Study

The framework of the project, which this work-in-progress paper is based on, was to investigate how open innovation can be promoted, nurtured, and facilitated by means of a digital platform. The need from the science innovation cluster for welfare technology (SICWT) was to move from a non-digital procedure of registering product ideas from companies or other stakeholders and facilitating connections between different stakeholders within the healthcare area, to a digital procedure through a platform designed to guide individual idea holders through the procedure of registering ideas and connecting with potential business collaborators. This study focuses on how such a digital registration roadmap can be designed to fit the digital platform by involving participants from the healthcare business sector and representatives from the SICWT in design thinking processes.

The participants in the study come from three different companies, which all are focused on innovation and have an interest in contributing to the development of a digital platform to support their innovative work. They were selected from the SICWT network of business collaboration partners and thus constituted a convenience sample available at the time the research should be carried out as well as willing to participate and contribute to the investigation [50]. We are aware that this kind of sampling lacks clear generalizability, a disadvantage which we tried to mitigate by involving the participants on a longer term through three iterations of DT processes over a time period of four

on which stage of the innovation process the design teams are in, but it also depends on the background and preferences of the individual designers in the teams. This chapter on related work will in the next step be further developed.

3 Theoretical Framework

Design thinking is acknowledged as a driver of creative and innovative processes [33, 34]. It does not have a clear definition and has been addressed in several different and nuanced ways, for example, as a methodology [35, 36], a culture, and a user-centered philosophy [37]. A general way to understand design thinking is to relate it to the ways designers think and as such it is mostly applied in the field of design research [38] and design education [39, 40]. Von Thienen et al. [41] state that a general agreement of design thinking is that it seems to be a successful practice in sparking innovation processes, but that a deeper understanding of this is hard to explain. Several studies have attempted to uncover principles, potentials, and challenges of design thinking-based innovation approaches [39–41]. In this regard, Leifer and Meinel [42:2], state that “cumulative work of a global design thinking research community /.../ have started to understand the underlying principles”.

In this study, the users were involved in iterative and co-creative design processes, where the focus has been on problem-framing, visualization, and experimentation by means of prototyping [cf. 43]. Sanders and Stappers [43] define co-creation as ‘any act of collective creativity’ and state that when co-creation is applied early in a design process, it has a positive influence on the design development. This in combination with involving the users as experts in a partnership, where the design process is carried out in an iterative manner provides conditions for the designer and other stakeholders to jointly develop an understanding of the different needs related to the design under development. This, in turn, will create a collaborative understanding of the problem- and design space [44]. In this regard, Stickdorn et al. [45] suggest prototyping as a way to materialize outcomes from such creative processes. In this paper, the prototyping is in low- as well as hi-fi formats and focuses on visualization and experimentation to understand how this influence and frame a co-creative design process.

Within the field of DT, a range of expressions for participants have been developed to help them imagine possible futures as well as exploring situations in them. One such expression is prototypes through which participants can express and experience ideas about situations that may become more apparent compared to abstract considerations alone [9]. According to Sanders and Stappers [9], creating a prototype and testing it, and improving it iteratively is most appropriate when a team has little experience with the situation at hand. The creation and testing of prototypes is useful to break down boundaries between design and implementation [21]. Hence, prototypes can function in activities investigating design possibilities, for example to inspire DT, to explore ideas, and to evaluate and enhance understanding. In the context of the present study, prototyping activities can be seen as a collaborative process through which the participants developed mutual learning [46]. Through visualization and experimentation through prototypes, the participants thus iteratively refined the prototypical design and step by step generated desirable results assessed against a predefined goal [47]. In this

and novel approaches, such in DT, where innovation can be achieved through experimentation. In general, research [cf. 12] advocates a strong need for collaboration across stakeholder disciplines emphasized by the actors' openness to combine different types of knowledge to better handle complex issues and exploring opportunities. However, there is a clear need for someone to be in charge and frame the direction for the work to at all accomplish innovative experimentations and solutions [11].

A strong claim is made underlining the importance and advantages of visualization as a support in a design thinking process [22, 23]. Anderson and Lilly [24:2], describe visualization as "a process of mentally constructing, shaping and understanding information and the ability to externally communicate it." [see also 22, 23]. In DT processes aspects such as communicating ideas and working towards consensus, or a common understanding of a problem are important parts of the visualization activity [16]. Other advantages are possibilities of organizing information in various ways, i.e., to beside text, include sketches, mock-ups, models, diagrams, knowledge maps which enable richer presentations and representations of information [8, 16, 25]. The visualization element also functions as a resource to facilitate collaborative work and co-creation of knowledge [26, 27]. In his study, Van der Lugt [28] illustrates how collaborative sketching supports team members in thinking processes and in storage of information as the sketching activity functions as a visible memory. However, the visualization element in DT differs throughout the design process [29] depending on whether visualization is used to support generation of ideas or decision-making [30]. Similarly, research [16] shows that the use of different visual formats leads to different design processes and design outcomes.

Another central theme in DT is the role of experimentation. Aspects relevant for experimentation work in design processes are iteration, trial-and-error, and prototyping [31]. Research has revealed that iterative processes is one of the key activities when it comes to innovation and decision-making [31, 32]. In their study, Rekonen and Hassi [6] investigated impediments for experimentation in novice design teams. The study pointed out that the participants in the novice design teams were resistant to work iteratively when involved in experimentation activities [6]. Furthermore, the novice design teams found it difficult to reframe the initial problem in cases where the first experiment did not support the idea being tested which led to stagnation and difficulties in moving forward in the design process [6]. This, according to the authors, is an aspect that distinguishes people in novice design teams from experienced designers where the latter find iterative processes as a natural part of approaching design problems. This is aligned with outcomes from a study by Efeoğlu and Møller [7], who also found that time constraint in DT processes with DT novices is a risk for the participants' engagement to decrease but on the other hand also constituting an opportunity to develop effective results under time pressure. Expressed differently, time shortage "can lead to a sharper focus on the design challenge, faster consensus-building and reflexive design acting based on the synthesis of insights." Björklund et al. [11] emphasize that experimentations in cross-disciplinary collaboration can foster flexibility and support and build communities to ensure design-driven experimentation. Beltagui, Bell and Candi [17] argue for the value of prototyping and iteration as tools for generating ideas, testing, and improving ideas, etc. What approach and what tools used in the experimentation process varies depending

promotion and uptake of product ideas within the public health area. The need for such a platform was initiated by a science innovation cluster for welfare technology (SICWT) in northern Denmark. The mission of the cluster is to through user-centered approaches connect partners, drive innovation, and create networks between companies, research institutions, and organizations within the field of innovation and welfare technology. The study included five participants from three healthcare-oriented companies and from the science cluster. They were all involved in a design thinking process towards developing a digital platform to connect stakeholders and promote innovation within this area. In this paper, we focus only on the development of a web-based interface (roadmap) for a digital platform that systematically can assist its users to register a product idea within the welfare technology sector and be connected to other stakeholders that have an interest in developing a similar kind of health promoting idea. The central research question is:

- How can a design thinking process including problem framing, visualization and experimentation elements provide a novice design team with resources to release problem-solving capacity based on their practical needs?

The continuation of the paper includes an overview of related work on visualization and experimentation in design thinking processes. Next, we shortly introduce a theoretical framework based on design thinking followed by the methods applied in the research. We finally end the paper with a short note on expected outcomes of the study. The data generated from the study is in process of being analyzed and therefore not included in this work-in-progress paper.

2 Related Work

This section presents an overview of research carried out in the field of design thinking with a particular focus on the effects of visualization- and experimentation elements in collaborative design thinking processes.

Design thinking (DT) is characterized as a human-centered approach to problem solving [15, 19, 20]. According to Brown [3, 4], organizations and companies can profit from being inspired by how established design teams think and work. Using such a human-centered approach can be beneficial in processes related to innovation, developing strategies for growth, developing strategies for better user satisfaction, product development etc. [3, 4, 19]. In relation to DT, co-creation is considered as a tool to push innovation and enhance democratic legitimacy [21]. In this regard, participants from local practices are crucial to ensure productive collaboration, overcome hindrances as well as to cope with emerging dilemmas [10, 21]. However, there is limited knowledge about how this can be done in practice.

Innovation through collaboration in DT is a central topic questioning how actors from different disciplines can respond to cross-disciplinary challenges as well as stakeholder complexities. In this regard, Björklund et al. [11] state that innovation hubs can represent an effective resource for developing new methods, techniques, and perspectives that can foster cross-institutional change. The authors further stress that a way to increase collaborative effectiveness across different stakeholder disciplines is to encourage creative

(DT) is a complex concept with a range of different definitions. Stanford d-school defines DT as “a methodology for creative problem solving” [8]. In his book, Brown [4:4], applies a more nuanced definition to the concept when stating that “Design thinking relies on our ability to be intuitive, to recognize patterns, to construct ideas that have emotional meaning as well as functionality, to express ourselves”. While agreeing with both of these definitions, the present study argues for a more distinct approach to the concept of design thinking. This is in line with a qualitative study carried out by Carlgren, Rauth and Elmquist [9] who argued that although several often process-oriented studies of DT exist, they are limited in taking account of what happens in practice. Based on an interview study carried out in six large organizations, their findings identify five different themes to frame a design thinking approach, namely: user focus, problem framing, visualization, experimentation, and diversity. Each theme is associated with principles, practices, and techniques, which together form a framework acknowledging DT both as an idea and as the enactment of the idea. In such DT framings, Stier and Smith [10] argue for the inclusion of co-creation referring to collaboration between different actors (e.g. from academy, industry, and societal partners) who together address existing challenges [11]. Similarly, Puerari [12] refers to such collaborations as multi-actor learning environments, where new methods and practices can be tested within real-world contexts.

According to Brown and Wyatt [13], the fundamentals of DT processes are inspiration, ideation and implementation. The authors describe these in the following way, “inspiration as the problem or opportunity that motivates the search for solutions; ideation as the process of generating, developing, and testing ideas; and implementation as the path that leads from the project stage into people’s lives” [13:33]. Although DT is growing in importance when it comes to managing innovation and creativity, the concept as such seems to be ambiguous and thus unclear in its practical performance [cf. 14]. This is particularly so in regard to novice design teams’ exposure to DT, where the research is limited [15]. A study carried out by Efeoglu and Møller [7] investigated how DT can be redesigned to accommodate the involvement of novices and non-designers with elaborated applicability of DT methods. Their findings from a real-life case study involving novices and non-designer as well as a survey involving a large sample of DT experts in software enterprises demonstrate that DT with regard to no-ndesigners can be simplified and redesigned for efficiency and effectiveness.

There is a strong discourse in the field of DT acknowledging the benefits of visualization and experimentation to facilitate and enhance the design process [16, 17]. However, while the use of visualization and experimentation methods in design thinking are frequently applied, there is a lack of understanding of the role visualization and experimentation plays in specific phases of design thinking [18]. In this regard, problem framing is considered as key to both visualization and experimentation situations. Framing the problem is about expanding and challenging as well as reformulating the problem rather than simply focusing on solving it [9].

This work-in-progress paper aims to contribute to the body of research on design thinking by forming a knowledge foundation on how problem-framing, visualization and experimentation can be used across the different phases in a design thinking process with novice designers to enable co-creative interactions. The study is based on a project targeting development of a digital platform connecting companies’ and other stakeholders’



Towards an Understanding of the Role of Visualisation and Experimentation in Design Thinking Processes with Novice Designers

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Abstract. Design thinking (DT) used by established design teams has been a topic for research since the 1960s. However, the use of design thinking in organizational settings carried out in novice design teams, that is, users with no experience of design and design methods can still be regarded as a newcomer in research. There is a strong discourse in the field of DT acknowledging the benefits of visualization and experimentation to facilitate and enhance the design process. However, research shows that there is a lack of understanding of the role visualization and experimentation plays in specific phases of design thinking. This work-in-progress paper investigates how a design thinking process can provide a novice design team with resources to release the team's problem-solving capacity based on the participants' practical experiences and needs. The study is based on a co-creation methodology including a DT process divided into four phases. Methods used were focus groups with a novice design team including five participants from three different companies within the field of welfare technology. In addition, participant observations were used to capture the participants' interactions within the different design phases. Expected outcomes will incorporate identified good practices and design guidelines. The study will contribute to unfolding knowledge about how participants from local practices can ensure effective collaboration to cope with emerging dilemmas.

Keywords: Design Thinking Processes · Novice Design Teams · Companies · Innovation Hub · Problem Framing · Visualization · Experimentation · Focus Group · Participant Observation

1 Introduction

Design thinking used by established design teams constitutes an area that has been a topic for research since the 1960s [1, 2]. However, the use of design thinking in organizational settings carried out in novice design teams, that is, users with no experience of design and design methods can still be regarded as a newcomer in research [3–7]. Design thinking

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exhibition locales. This would also provide an avenue to discern the viability and inherent challenges of deploying exploration games across a spectrum of exhibits, spanning from art to natural history.

In conclusion, with XTR, we unfurl a novel paradigm wherein the act of playing games can transform visitors in an exhibition site into explorers in a knowledge playground.

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content. This may be attributed to a disjointed exhibition design that disorients visitors, or challenges in navigation, or perhaps a discord between the museum's intended visitor experience and the actual motivations or intentions of the visitor.

In our research, we posited that the amalgamation of mobile media technologies and mixed reality games holds promise for self-navigation in automated exhibits. The feedback was overwhelmingly favorable toward XTR, an explorative game. Participants recurrently expressed that the game enriched their visit, promoting proactive engagement and assisting with navigation. Crucially, XTR conferred a sense of continuity to what might otherwise feel like a fragmented exhibition landscape. A salient revelation from our study underscores the pivotal role of cultivating visitor interest. Although many participants were not initially drawn to the exhibit out of personal intrigue, engagement with XTR uncovered elements they found captivating. Hence, participants manifested a receptivity to exploration games, irrespective of whether they embarked on the museum journey solo or in groups. Crafting an environment conducive to exploration has the potency to ignite curiosity, subsequently kindling genuine interest. Games can be intricately woven to perpetuate this engagement and amplify this burgeoning interest via active user participation. Yet, it's essential that these games allow visitors the latitude to immerse themselves in any artifact they deem intriguing, facilitating contemplation rather than herding them toward a prespecified endpoint. Consequently, the value proposition of exploration games, especially in reinforcing user experiences in automated settings, was underscored.

XTR was envisioned as a digital aide to assist visitors with navigation, offer insights akin to a human guide, and extend this support to groups, acknowledging that many choose to experience exhibits collectively. Beyond the dimension of navigational assistance, the transmission of information was also at the forefront of our exploration. The multifaceted challenge bifurcated into the realm of self-navigation in automated environs and harmonizing enlightenment with experiential depth. Addressing this conundrum, XTR ingeniously interweaves game design facets, buttressed by psychological and cognitive paradigms pertaining to motivation drawn from adventure games, seamlessly into the exhibit milieu. Drawing from our empirical research at the HMR, XTR reimagines exhibitions as fertile grounds for experimentation, the cultivation of unique interests, and the application of newfound insights beyond the confines of these knowledge sanctuaries to real-world scenarios. This elevates mundane routines into rich experiential narratives ripe for discovery. When a player immerses themselves in a game within an exhibit, the demarcation between playing and visiting becomes increasingly blurred. Echoing Dewey's earlier [106] sentiments, irrespective of its enlightening or experiential quality, any event that deviates from the mundane rhythm of life is an experience in itself.

In essence, our research underscores the potential of exploration games to facilitate visitor engagement within automated exhibition spaces. Mobile adventure games can be harnessed to accentuate the traits of curiosity, exploration, and discovery, all pivotal for self-navigation and kindling personal interests. Through the meticulous design, realization, and assessment of XTR, we have spotlighted three pivotal design strategies for digitally mediated solutions in analogous contexts. Future endeavors should escalate in scope, embracing a diverse methodology and augmenting the pool of participants and

repeated interactions with familiar content yield fresh experiences. Feedback from user trials highlighted participants' keenness to delve deeper into the system's exploration capacities. Thus, a compelling design avenue lies in amplifying the scope for variability and unique experiences in consecutive or extended game interactions.

Post the culmination of this study, exploration as a core game mechanic was spotlighted in subsequent research, encapsulated by the "exploration-exploitation dilemma" [67]. This pertains to the act of information collection and leveraging accumulated knowledge to reap rewards. XTR's reward mechanism centers on information discovery, which could potentially be its primary allure. Introducing random exploration combined with reward mechanisms via a "systematic switching" approach, which promotes uncertainty-driven exploration, merits further exploration [67].

This study did not harness user behavior models to scrutinize patterns in user movement during gameplay. However, prior studies have delineated user archetypes such as *ant*, *butterfly*, *fish*, and *grasshopper* based on observational insights in museum settings [56]. These archetypes could potentially be harnessed as analytical tools in subsequent research. An intriguing proposition is discerning whether user behavior exhibits shifts when engaged with or without an exploration game like XTR. The *explorer* persona, as defined by Falk and Dierking [104], was pivotal during the nascent stages of this research, underscoring the importance of exploration in game design. Further iterations could potentially integrate diverse user personas to cultivate a more holistic user experience.

Reconciling the dichotomy between user autonomy in exploration and system-driven directionality emerged as a notable challenge. Although guiding users necessitates some level of system-driven direction, this seemingly contradicts the principle of granting users the freedom to follow their intrinsic interests. This tension parallels constraints observed in linear narratives. Our attempt to mitigate this tension led us to the exploratorium model. Beyond the systematic switching strategy, existing literature delineates the distinction between emergent goals and imposed objectives. Rozendaal et al. [105] associate emergent goals with user-driven creative and improvisational actions, an aspect worth considering in future research endeavors to inform game design iterations.

On a technical front, challenges arose with Bluetooth beacons for location tracking. While these beacons can pinpoint a user's location, they often miss contextual nuances. For instance, a user might be proximal to an exhibit but might be oriented away from it. Challenges were further exacerbated by inconsistent tracking performance across different device types, with notable discrepancies observed between iOS and Android devices.

5 Conclusion

The primary goal of this study was to delve into curiosity and exploration as foundational tenets for designing digitally mediated experiences tailored for automated venues, leveraging cutting-edge mobile technologies. The insights gleaned from this research pave the way for the design and deployment of analogous computer-mediated technologies in automated exhibitions to bolster the museum-goer's experience. The term "support" encompasses scenarios wherein exhibitions face hurdles in transmitting their

than individual pursuits. This dimension of shared experiences remains an uncharted territory deserving further exploration.

Our insights align with existing literature, offering a deeper understanding of the design intricacies pivotal for interactive mobile systems tailored for self-guided exhibition scenarios. The primary takeaway underscores the imperative for a seamless integration of the digital overlay with the physical exhibition layout. This synergy should be at the forefront of system design, ensuring efficient navigational support and enticing users to explore lesser-trodden paths. Furthermore, the presentational sequence should grant users autonomy in their exploration. XTR's demonstration highlighted the liberty it offered users in charting their unique courses.

A secondary design insight revolves around the cohesion introduced by the digital layer. Prior to XTR's inception, visitors often reported a lack of thematic coherence in the HMR. XTR's introduction offered a more integrated experience, bridging the gap between gaming and museum exploration, which received commendation from users. Ensuring coherence thus emerges as an indispensable component, especially for exhibitions perceived as disjointed.

Lastly, the motivational facet of XTR, embedded in its design to spark curiosity, facilitate exploration, and catalyze discovery, merits attention. While achieving a balance between enlightenment and experience within a game framework poses challenges, XTR's design illustrated that users were indeed prompted to explore, discover hidden gems, and accrue knowledge. This suggests that designing exploration games with these principles at the forefront, especially in the context of self-guidance, is a promising avenue.

4.1 Design Tactics for Exploration Games

Here, the design insights are summarized as design tactics proven to be important to consider by this study as guiding design principles: 1) Link the digital game layer and the physical layout of the exhibition with the freedom to choose one's own path; 2) A coherent exhibition experience should link activities in the digitally mediated layer with the physical exhibition site and its exhibits; 3) Curiosity, exploration, and discovery for interest development and guidance, manifested through (adventure) game design and mechanics, must be the core design principals.

4.2 Limitations

Curiosity, undeniably integral to the act of play, thrives on novelty, whether in the form of sensory indulgence or cognitive challenges encompassing problems, strategies, or narratives. Expecting a game to retain its appeal over time without incorporating design elements fostering novelty would be a misjudgment. Games devoid of mechanisms to perpetuate this sense of novelty often witness a fleeting spike in motivation, a phenomenon colloquially termed the "novelty effect" [41, 68]. XTR is exempted from this critique, given its objective is to enhance the user experience during a single exhibition visit rather than repeated engagements. If XTR's remit were to span multiple visits, it would necessitate extrinsic motivators beyond mere curiosity and interest. One promising strategy to foster replayability lies in emergent game dynamics; these dynamics ensure that even

unique experience, like reconstructing the historical redoubt. Notably, terms like “ravelin” became clearer through XTR’s visual references: “The word “ravelin” is unfamiliar to me. Without the references provided by XTR, I would never have understood its significance.” [SOLO 01]. Participants felt more invested and curious, with the game enhancing their understanding and enjoyment of the exhibition.

4 Discussion and Limitations

The development of XTR was informed by prior studies on design and technical implementation for crafting mobile guides tailored to exhibitions. This research surpasses previous endeavors by focusing on designing for automated sites, emphasizing curiosity, exploration, and discovery as primary design principles. Such design principles facilitate probing the following research questions: How can a game-guided, exploratory system assist users in automated sites? Additionally, how might a game be constructed to foster an environment conducive to individual interests?

Initially, we postulated that the fusion of mobile media technologies and mixed-reality games might be instrumental for self-navigation within automated exhibitions. Our primary focus revolved around the utility of games to engender exploratory behavior, thereby igniting curiosity and sustaining interest. This could potentially harmonize the dual objectives of enlightenment and experience while aiding users in navigating automated exhibition sites. Consequently, we embarked on a journey to discern how mobile devices can be intermediaries for exploration and self-guided automation. The objective was to scrutinize the feasibility of digital adventure games in harmonizing the often-conflicting expectations of automated exhibitions.

To address the primary research question, this study pivoted around the conceptualization of digitally mediated experiences tailored for automated exhibitions. Further complicating the design process is the existing dichotomy in the museum narrative: should museums primarily educate or entertain? Our response was the design of a mixed-reality mobile game, drawing elements from adventure games, thus converting exhibition sites into knowledge-rich playgrounds. This transformative approach champions the user’s motivations over the museum’s intent. Feedback from XTR play testers corroborated that the game augmented their museum experience, offering navigational assistance, promoting exploration, and revealing hitherto undiscovered facets of the exhibit. Such positive responses to the game-guided exploration suggest future museumgoers might readily adopt this model. This observation harmonizes with prior research, allowing us to delineate the game design elements that resonate within this context.

Our secondary research question delved deeper into how games can foster environments reflecting individual interests. Our analysis unveiled that XTR adeptly facilitated shared experiences, creating a framework wherein users could tailor their journey based on their primary motivations for the visit. The marriage of the virtual layer with the physical realm demonstrated a potent mechanism to educate and enlighten users. A recurrent observation was the users’ appreciation for the digital visualization of the redoubt as they navigated its physical counterpart. The term “interests” would perhaps be a more accurate reflection than “personal interests,” as many users identified shared interests rather

“Because of the link between the physical and the digital, where the game leads one to certain locations, we entered the powder chamber instead of walking past it.” [FAMILY 03, Father].

In the given scenario, the powder chamber door was sometimes closed, leading visitors to assume it was off-limits. When open, the “powder chamber” sign was obscured, causing some visitors to unknowingly enter and leave the chamber. Despite the presence of informative posters, XTR’s outdoor information was praised for enhancing exploration. Notably, many visitors missed the significant whale vertebra exhibit at the entrance, only realizing its presence through XTR. For some, the game even lengthened their museum visit:

“If not for the game, we would have just walked around and left after a short while, but with the game, there were objectives in the game that I wanted to solve.” [FAMILY 01, Mother].

Participants highlighted content they would’ve overlooked, like the unusual tale of a priest who concealed a gun during WWII. This story was spotlighted by XTR’s quiz, prompting visitors to revisit and absorb it, describing it as “funny” and “peculiar.” On the social aspect, users felt that XTR fostered a collective play experience among groups, enhancing social bonding and guiding their visit. Some even engaged in competitive gameplay within their groups through XTR. Consider the example below:

“We wouldn’t have moved around outside without the motivation the game provided. We would probably have stood at a distance and viewed the rampart instead. It was cool to wander around the ramparts.” [FAMILY 03, Father].

Coherent Exhibition Experience Through Digital Mediation

One participant stated, “The museum exhibition feels like a moebius strip without an app like this” [SOLO 01]. Many from the Bravo group felt the exhibition was too “compact” and “confusing”, lacking coherent themes. The abundance of reading material discouraged some visitors: “Playing made me active and investigative instead of simply walking around. I didn’t even want to read any of the signs; there was too much to read.” [FAMILY 01, man]. However, the game provided structure, enhancing the overall exhibition experience: “The exhibition was a mess with a lot of things... the game supported the journey through the exhibition” [FAMILY 03, Father].

Interest Development Through Curiosity, Exploration, and Discovery.

One visitor noted, “Usually, I stand at a distance from the exhibits, but the game made me have to walk in close proximity to certain things, which made me look closer than I would have” [FAMILY 01, Mother]. Another commented, “Usually, I find museum visits boring, but playing a game flips the visiting experience upside down.” [Family 01, Father]. The game’s design encouraged visitors to engage more deeply with exhibits and information: “It was great that XTR made me focus my attention on specific information, and that I had to activate the knowledge I acquired in the game.” [SOLO 03].

However, some criticized XTR for making them focus too much on screens instead of landmarks and suggested improvement like a notification system to guide them. Despite such feedback, many appreciated the game’s physical-virtual integration, allowing for a

Table 2. List of participants from Bravo.

Team	Social constellation	Adults	Children (age)	Total
BRAVO	Family 01	2	1	3
	Family 02	2	2	4
	Family 03	1	2	3
	Couple 01	2	0	2
	Solo 01	1	0	1
	Solo 02	1	0	1
	Solo 03	1	0	1

Bravo participants visited the exhibition sporadically, ensuring they experienced the content without pressure. They were observed and interviewed on-site. In the following, the XTR experience is described in three overarching themes articulated to target information specifically for the aim of this study: 1) Self-guidance through mixed reality exploration games; 2) Coherent exhibition experience through digital mediation; and 3) Interest development through curiosity, exploration, and discovery. The first theme is related to the guidance aspect in an automated exhibition site; the second theme is linked to the utility an exploration game like XTR provides users with, in an exhibition that is perceived as a “fragmented experience”. The third theme takes aim at the theory posited by Csikszentmihalyi and Hermanson [40] that exhibitions can be designed so that curiosity can serve as a trigger to take hold of the visitor’s attention, which could lead to extensive interaction leading to interest development, a key to learning. While the study wasn’t focused on measuring “learning”, it evaluated how curiosity-driven exploration games might enhance user motivation and interest at automated sites. Additional observations, not aligning with the themes, revealed diverse game-play patterns among users, such as competition or collaboration. These insights hint at the need for game design to accommodate both cooperative and competitive elements.

Self-guidance Through Mixed Reality Exploration Games

After engaging with the exhibition and XTR, participants highlighted key moments from their visit. Both Bravo and Alpha teams initially overlooked the entrance’s significance, known as the ravelin—a protective drawbridge of the star fort. However, an XTR node, presenting a virtual reconstruction at the ravelin, illuminated its historical and architectural importance for them. Consider the example below:

“Getting information through play is a lot more fun than just having to go around and read. The game also draws attention to specific things that I can focus my attention toward, instead of not knowing that to examine or look at, in an exhibition that has so many things that are not interesting to me.” [SOLO 01].

Participants also noted that XTR made them aware of their physical traversal of the exhibition site and that there would have been areas they would not have discovered or seen, such as the powder chamber, had it not been for the game’s guidance through nodes. Consider the following statement:

- *Below average*: 50% of the results in the benchmark are better than the results for the evaluated product, 25% of the results are worse.
- *Bad*: In the range of the 25% worst results

Figure 5 shows the benchmark graph from the UEQ for XTR. Table 1 presents the interpretation these values along with a comparison to benchmarks from the UEQ database.

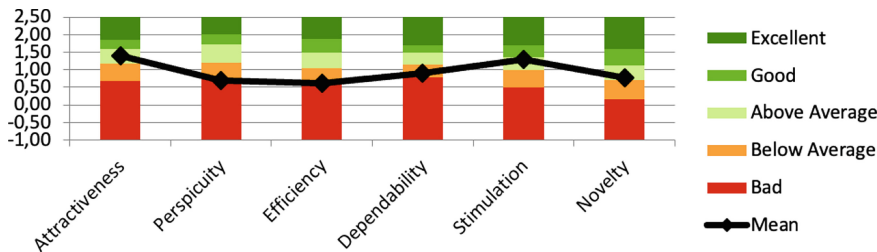


Fig. 5. Benchmark graph for XTR.

The table shows that the overall impression of XTR was above average. However, in terms of perspicuity, i.e., how easy it was to learn, it scores ‘bad’. Efficiency and dependability, i.e., can users solve their tasks without unnecessary effort and does the user feel in control of the interaction is below average, while stimulation and novelty, i.e., is it exciting and motivating to use XTR and whether is it perceived by the users as innovative, creative, and interesting to use or not, scored above average.

Table 1. Table with benchmark comparison results and their interpretations along with the scale means

Scale	Mean	Comparison to benchmark	Interpretation
Attractiveness	1,39	Above average	25% of results better, 50% of results worse
Perspicuity	0,69	Bad	In the range of the 25% worst results
Efficiency	0,63	Below Average	50% of results better, 25% of results worse
Dependability	0,89	Below Average	50% of results better, 25% of results worse
Stimulation	1,28	Above Average	25% of results better, 50% of results worse
Novelty	0,78	Above Average	25% of results better, 50% of results worse

From this, it is possible to evaluate that XTR certainly has room for improvement in terms of usability, but from a user experience point of view, it has had a positive effect on the participants from Alpha and Bravo.

XTR User Experience: Conversations and Observations

Users from Bravo tested XTR and participated in a debriefing interview. The interview material was partially transcribed and analyzed qualitatively. Some excerpts were translated from Danish to English by the authors. Table 2 lists Bravo participants, indicating their group details or if they visited solo, and uses anonymized labels to reference quoted interview excerpts.

during the analysis of the form data from the UEQ, it was revealed that one question (question 11). This error has consequences for the Dependability score and the question started with a negative term, obstructive as opposed to supportive. This means that the result for dependability is not precise.

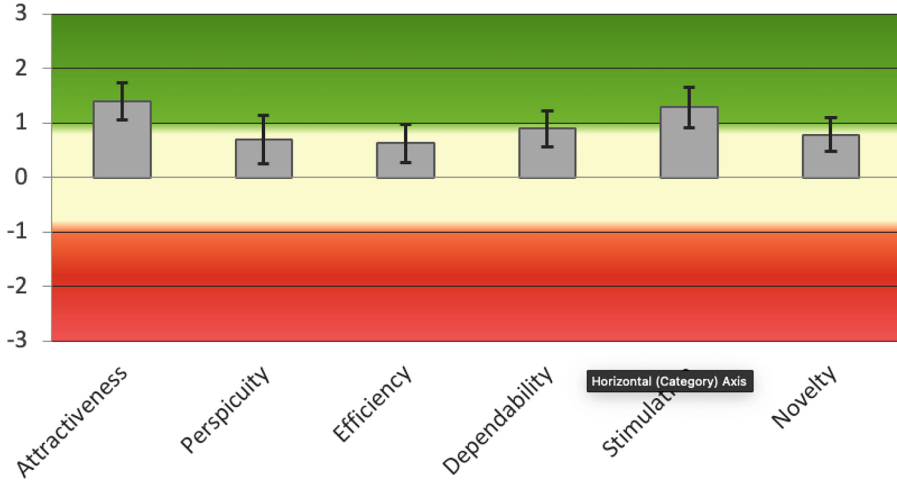


Fig. 4. The scale means from the UEQ test. The standard interpretation of the scale means is that values between $-0,8$ and $0,8$ represent a neutral evaluation of the corresponding scale, values $>0,8$ represent a positive evaluation and values $<-0,8$ represent a negative evaluation.

The Alpha participants were recruited on-site from guests who visited the site on their own volition, unlike Bravo participants, who were recruited to participate in a qualitative test of XTR beforehand. In total there were 30 participants who completed the UEQ questionnaire.

Due to the sample size ($n = 30$) the Cronbach-Alpha coefficients ($\alpha = n * r / 1 + (n - 1) * r$, where r is the mean correlation of the items in a scale and n is the number of items in a scale) were not factored into the results presented here. The user experience of XTR from the UEQ test is presented in Fig. 4 as scale means and the benchmarks are reported in the graph in Fig. 5.

The user experience is measured by comparing the results from XTR to a benchmark database containing reports created with UEQ for other products. The benchmark currently contains data from 452 product evaluations with the UEQ, with a total of 20190 participants.

The benchmark classifies the user experience of XTR into five categories (per scale) [101]:

- *Excellent*: in the range of the 10% best results).
- *Good*: 10% of the results in the benchmark data set are better and 75% of the results are worse.
- *Above average*: 25% of the results in the benchmark are better than the result for the evaluated product, 50% of the results are worse.

The initial questionnaire collected descriptive user data, including demographics and player type psychographics. It contained questions on age, gender, social constellation, and prior experience with location-based games. The player-type section utilized the Hexad inventory, determining player type through a 7-point Likert scale.

During gameplay, the test facilitator observed and documented user interactions through pictures, videos, and notes. The application also captured behavioral data, such as movement patterns, sequence of node unlocks, and time spent at each node.

The post-visit questionnaire gathered feedback on the player experience (PX) and overall quality of the visit. It explored user motivation, digital competencies, and overall experience using the UEQ. Further questions delved into users' gaming habits and the game's influence on their museum visit, including any new discoveries facilitated by XTR.

For Bravo participants, a concluding interview explored the broader visiting experience. It addressed topics like the holistic experience of the automated site with digital media and the impact of XTR on the visit's enlightenment and overall experience, focusing on technology-mediated self-guidance.

3.2 Results

For the study reported here, the UEQ supported by observations and interviews was the source of data used to report on users' experiences of playing the game. While Hexad and analytics provided knowledge about other aspects, they were omitted for the sake of focus in this study: to report on how curiosity and exploration as game design principles for a self-guided system for automated sites affect user experience. The analytics logged within the application were omitted from this study due to data corruption from some play sessions.

These may be revisited at a later point. The study aimed to investigate curiosity and exploration as design principles to facilitate and mediate automated exhibition content. From the test, Hexad provides insight into what motivates a particular player, while the UEQ inventory provides insight into the user experience of playing XTR in an automated site. The following insights from this study are based on three sources of data: questionnaires, observations, and interviews.

XTR User Experience: User Experience Questionnaire

The following details the data from the UEQ, which summarizes the findings from playtesting XTR at the exhibition site. The UEQ consists of 26 questions in the form of a semantic differential, i.e., each item is represented by two terms with opposite meanings. The 26 items provide data for 6 scales: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. Attractiveness is a pure valence dimension. Perspicuity, Efficiency, and Dependability are pragmatic quality aspects (goal-directed), while Stimulation and Novelty are hedonic quality aspects (noy goal-directed). The order of the terms is randomized per item, i.e., half of the terms of a scale start with the positive term and the other half start with a negative term. A seven-stage scale is used to reduce the central tendency bias for such types of items. An example of an item is: **attractive** × × × × × × **unattractive**. The items are scaled from -3 to +3. Thus, represents the most negative answer, 0 a neutral answer, and +3 the most positive answer [101]. Note:

3.1 Process

As mentioned, the test was executed on-site as a study in the wild [93, 95], which is an approach where researchers move from controlled lab-based experiments to the real intended settings. A total of 18 participants were recruited among visitors. We also enlisted an additional 11 participants who were invited to participate in a more detailed study with a concluding interview. The procedure for the recruitment was facilitated by a researcher, where visitors were greeted, and if they agreed to partake in the study, they were briefed about the game and informed about data collection, subsequently signed consent forms, and assisted (if needed) in downloading XTR onto their devices. Following gameplay was a questionnaire. After the participants had filled out the questionnaire, they were free to play the game as they saw fit and explore the exhibition as visitors, but they were instructed to return to the test facilitator when they were finishing up for a follow-up questionnaire. If they were curious, they were allowed to ask questions or redact their consent and opt-out of the test at any given time.

Bravo was interviewed as their final step after the follow-up questionnaire to clarify different aspects of the experience and to gather additional qualitative insights. For both groups, the XTR application ran analytics in the background, logging user interactions and the sequence of beacon unlocks. As such, there were essentially two data collection procedures where one included a more in-depth qualitative probing through interviews.

Methods and Inventories

The study employed mixed methods, utilizing self-reporting questionnaires, a semi-structured interview, and in-app analytics. This allowed tracking of game runtime, crashes, and other metrics. A major tool was the Hexad inventory [96, 97], which identifies player types based on motivations for playing games. Hexad, grounded in self-determination theory [98], classifies players by intrinsic or extrinsic motivational factors [99], thus informing game design decisions. The study used Hexad to discern which game styles would likely resonate with HMR visitors.

The primary data source was the User Experience Questionnaire (UEQ) [100–102], assessing users' subjective impressions of a product's experience. UEQ, a 26-item semantic differential scale, was selected because of its broad application, capturing the overall museum visit experience rather than just the game aspect. It takes about 3–5 min to complete, offering a swift data collection method for gauging product quality. While other specialized tools like the Museum Experience Scale [103] exist, the study opted for a more generalized tool to encompass a wider scope of user experience. Both Alpha and Bravo participant groups followed the same procedure, but Bravo also had a follow-up interview to gain deeper qualitative insights.

Test Protocol

Participants were recruited at the site for XTR playtesting. After signing a consent form, they completed a questionnaire, were briefed about the test, and introduced to the game on their mobile phones. A demo node at the armory building entrance illustrated the game's core mechanism. Participants could then freely engage with the game and other site activities. After their visit, a debriefing took place involving a second questionnaire and feedback session.

A different approach is to have an open structure without a story arc. This is the form typical of simulation-based games, strategy games, and open-world games, such as massively multiplayer online roleplaying games (MMORPGS) [89].

- An *exploratorium* is a linear structure in which the player can pause to explore the surroundings [90]. This story structure provides a structure that allows the player freedom to be inquisitive about objects that suit individual interests and skip anything that is uninteresting, while still progressing the player from beginning to end.

The *exploratorium* structure was a focal point in the design of XTR. It provides a pathway from start to finish, yet simultaneously invites visitors to engage with objects at their individual rhythm. Within the context of museum visits, this model presents an experience that is both guided and liberating. It effectively counteracts “museum fatigue” [91, 92] by empowering visitors to determine their own pace and trajectory. In summation, for the XTR iteration, the *exploratorium* was selected owing to its harmonious blend of structure and autonomy. This design caters to a visitor’s dual inclination towards gaming and acquiring knowledge. The *exploratorium* model honors visitor predilections and the intrinsic human impulse for exploration, especially in the realm of mobile applications.

3 Experiment Design for an Explorative Exhibition Experience

The study aimed to assess how XTR influences users’ explorative behavior and fosters a space for them to engage based on personal interests. It sought to determine users’ acceptance of game-guided support, the effectiveness of situated digital storytelling for knowledge acquisition or entertainment, and how the game influenced users’ physical exploration. The study adopted the *research in the wild* approach from the HCI tradition, emphasizing real-world testing over controlled lab environments [93–95]. The research was carried out at HMR between October 14th and 24th, 2019.

Prior to the main study, off-site pilot studies assessed the technical aspects of XTR. Issues related to Bluetooth beacons, game content, graphics, and text were addressed. After these modifications, beacons were integrated into the exhibition site. The game was also adjusted based on factors like device type, user concurrency, and weather conditions. XTR’s tested version was in Danish, limiting it to Danish-speaking users.

The research methodology combined both qualitative and quantitative data collection methods. Data came from two participant groups: *Alpha* and *Bravo*. Alpha participants were recruited directly at the exhibition, while Bravo participants were recruited both on-site and before their visit, with assistance from the collaborating museum. Alpha had 18 participants (13 females, 5 males) aged between 9 and 65, with 13 being first-time museum visitors. Bravo consisted of 12 first-time visitors (7 males, 5 females) aged between 11 and 42.

The goal was to involve a diverse set of participants, including individuals, families, and couples who might typically visit the exhibition. Previous data from HMR indicated most visitors were from Denmark and Germany, spanning various age groups. For this study, participants encompassed a mix of multi-generational families, couples, and solo visitors. All participants were Danish citizens. The study aimed to represent those who’d engage with the exhibition content based on their genuine interests.

2.5 Locational Narratives for Exhibition Visits

Museum visits epitomize intricate yet enriching encounters, modulated by factors such as time, personal inclinations, and pre-existing knowledge. While the immediate recall of these experiences might elude many visitors, specific stimuli can subsequently rekindle these memories. A potent strategy to bolster such recall and introspection is by juxtaposing a narrative learning framework with the tangible environment of the museum. Narratives, pivotal in the human learning process, offer a scaffolded structure to assimilate experiences [81–84]. Inherently, most visitors are driven by intrinsic motivation, magnetizing towards experiences that resonate with their curiosities. The constructivist learning paradigm characterizes learners as dynamic contributors, prioritizing experiential learning over mere rote memorization. Thus, crafting delineated learning pathways within exhibits can synergize activity, education, and narrative.

Historically, storytelling has been enmeshed in the fabric of cultural institutions. The technological zeitgeist of today empowers museums to venture into the realm of digital narratives. Nevertheless, a prevalent contention is that such technological integrations might fragment the visitor’s attention, potentially diluting the primary experience.

XTR’s narrative architecture is underpinned by seminal research on mobile narrative trajectories in museums. We delved into the art of narrative framing within both museum and gaming landscapes, identifying congruities in their storytelling matrices. Gleaning insights from seminal texts like “Weaving Location and Narrative for Mobile Guides” [84] and “Story Structures: Building Narrative Trails in Museums” [85], we amalgamated these findings to sculpt XTR’s narrative orientations and gameplay content. Our overarching ambition is to fuse traditional museum encounters with the allure of digital narratives, crafting an enthralling exploration game.

The “storycraft” model [86] is an innovative approach that interlaces space, temporality, and narrative. It demarcates varying degrees of interactivity, spanning from rudimentary interface engagements to intricate, dynamic user-curated tales. Through this model, users weave narratives by forging conceptual linkages amongst artifacts.

Several narrative structures useful in digital storytelling are mentioned throughout the literature, useful for implementing narrative structures for interactive storytelling [87]:

- A *tree* has a linear flow with a beginning and multiple separate endpoints. This is most common in text-based work due to its low costs.
- *Nodal*, or a *dead-end structure*, is typically found in action/adventure games and involves numerous alternative paths and dead ends, which may or may not be (but usually are) reversible, generally along a main sequence eventually leading from the beginning of the game to the end [88, 89].
- *Parallel plot structure*, in which different versions of the story are told at the same time, and the reader/viewer can switch between the different parallel versions [81].
- *Modulated*, or the *dynamic labyrinth structure*, provides constellations of interactive choices but only allows access to a new set of possible interactions after the player has experienced different parts of the story [81]. Game levels function in this way.
- *Open structures* in which story elements are associated with different physical places and links between places are open, so the player can wander around discovering different elements of the story [90]. This is the form typical of early adventure games.

exertion wasn't the primary focus of this study, it remains a potential avenue for future research.

Workshop discussions settled on a smartphone game app using cross-platform Bluetooth frameworks compatible with iBeacon and Eddystone protocols. Bluetooth beacons, offering clues tied to specific locations, were integrated to leverage the physical indoor and outdoor exhibit spaces. These were selected for their unobtrusive integration capabilities. Without on-site WiFi, standalone networks between mobile devices and beacons, termed “fog” networks [51], were established.

XTR, is a location-based game built in UNITY for modern smartphones with Bluetooth and 3D-graphic features. It's available on both Android and iOS through BYOD approach. Users downloaded it from the respective app stores and received instructions on-site. The game employs 15 Bluetooth beacons (10 indoor, 5 outdoor) to guide users towards key points in the exhibition, nudging them towards lesser-explored areas of the redoubt.

2.4 Game Mechanics

The game, XTR, combines two modes of play: *explorative exhibition* and *exhibition quiz*. The *node proximity* overview (see Fig. 3) guides players using iconography and labels, resembling a “hot or cold” system, with colors indicating the beacon's distance. The default mode is the explorative exhibition: an outdoor game spanning the redoubt. In contrast, the exhibition quiz takes place inside the armory where the primary exhibits reside. Both modes utilize scavenger hunts and puzzle-solving, but their unlocking mechanisms differ.

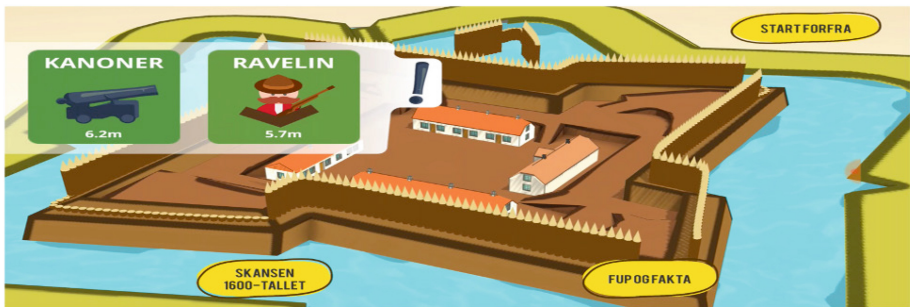


Fig. 3. Screenshot showing the distance indicator, which shows an approximate distance in meters, as well as colors that indicate when the player can interact with and unlock a node.

The gameplay aims to merge game and exhibition, allowing users to explore and reapply knowledge in a constructivist, experiential learning manner, emphasizing the importance of narratives in learning. The game's design and structure in XTR promote a blend of interactive exploration and structured narrative learning called *exploratorium*.

2.2 Curiosity and Exploration Framed as *Exploration Games*

In response to prevailing challenges—especially the need for thematic cohesion and the imperative to guide visitors towards the less conspicuous segments of the redoubt—XTR was conceived. Its primary objective was to provide thematic unity to the exhibition site, spur users' curiosity with exploration facets, and consequently enhance the overall visitor experience.

The paradigm of exploration games serves as an effective conduit for melding enlightenment with experiential immersion within an exhibition space. Succinctly, the game aims to seamlessly integrate education, entertainment, and guidance, thus ameliorating the user experience in an automated setting. To address the challenges outlined, this research pivots to the adventure games genre, drawing upon its array of design elements and mechanics, which collectively shape the architecture of XTR. In its current iteration, XTR employs two core explorative components: thematic/topical coherence achieved via storytelling and puzzle-solving, and directionality facilitated by a scavenger hunt motif.

Subsequent sections will delve deeper into the specific design patterns culled from adventure games that have been integrated into XTR. It's noteworthy to mention, however, that the prioritization of goals—be it primary, secondary, or tertiary—was intrinsically tied to individual users, calibrated according to their unique interests and motivations.

2.3 System Design and Explorative Elements of XTR

The game design of XTR emerged from a cooperative co-design process involving the HMR custodian, curator, an elementary school teacher, a museum inspector, and the game's development team (see Fig. 2). This method emphasizes the importance of multidisciplinary involvement in crafting digital narratives for museum settings, with co-design being pivotal [77, 78]. Such participatory methods in the cultural and educational arenas allow domain experts to collaboratively design interactive storytelling solutions [79, 80]. While museum professionals and the teacher determined the content, developers oversaw the technical side. The curator's role was advisory, leveraging visitor insights.



Fig. 2. Left and right photos show design workshops with a team of custodians, curators, schoolteachers, the museum inspector, the exhibition designer, and application developers.

The game's intent was to instill a sense of discovery through exploration, all grounded in the physical traversal of the museum site. Although immersion through physical

structure to an automated model. This innovation marked the pioneering step among multiple sites overseen by the Historical Museum of Northern Jutland. Unlike their larger counterparts, which usually benefit from generous funding and commercial oversight, smaller heritage sites such as the HMR grapple with distinct economic constraints, which inevitably shape their growth trajectories. The designation of HMR as a protected site imposes further restrictions; for instance, outdoor exhibits cannot incorporate conventional informational aids like posters, which curtails certain design possibilities.

In its current state, devoid of onsite staff, HMR is underpinned by automated security mechanisms, encompassing features like timed locks and surveillance cameras. This metamorphosis is driven by a vision to streamline operations across smaller venues, tackling fiscal hurdles by providing complimentary access, thereby sidestepping potential shutdowns due to financial inadequacies.

Narratively, HMR is a tapestry of interwoven stories, absent of a linear trajectory. It traverses epochs, from the inception of the redoubt in the 1600s, its tenure as a German stronghold during World War II, to diverse exhibits showcasing maritime relics and narratives pertaining to the coastal village and its environs. The exhibition also delves into portrayals of Hals' quotidian life since the 1970s and elucidates on the village's ecclesiastical heritage.

Empirical observations, both prior to 2016 and after the 2018 overhaul, underscore palpable shifts in visitor engagement. In the open spaces, patrons were observed to indulge in playful exploration, utilizing the expanse for recreational pursuits, exemplified by activities such as cavorting around the cannons (refer to Fig. 1: left). Conversely, within the indoor confines, the elder demographic exhibited a propensity for contemplative perusal, while their younger counterparts seemingly exhibited detachment. Nonetheless, replica soldier attires, proffering hands-on engagement, evoked universal fascination (as depicted in Fig. 1: right).



Fig. 1. Left: An aerial overview of the exhibition site, with the house museum containing the exhibited artifacts. Source: Google Maps. Right: A visitor poses with the replica costume

There were challenges in conveying the multifaceted narrative, guiding visitors, and highlighting the redoubt's significant features. Many visitors overlooked the architecturally significant powder chamber and the vital ravelin drawbridge, even while using it. A typical visit to the museum lasted 30–60 min, which is consistent with other studies where the timespan has been reported to be 31–105 min for families [75]. The average attention span of a visitor to an exhibition is about 30–45 min [76].

and homing in on innate motivations. Curiosity is the lifeblood of this paradigm, nurturing exploration, immersion, and awakening a reward system geared towards novelty [40].

In synthesizing the intricate web of curiosity, exploration, interest, and motivation, a foundation is laid for devising a mobile game guide tailored for users. Adventure games, typified by their curiosity-fueled puzzle-solving ethos, mirror our theoretical scaffolding. Transmuting users into players, these games beckon them to traverse exhibitions in a ludic ambience. Such games craft bespoke experiences, welding knowledge imbibing with tangible real-world applications.

2 Designing Explore the Redoubt

Curiosity and exploration are central to the design of XTR. In particular, we have zeroed in on curiosity because it fosters exploration, a critical activity through which organisms seek information that they can use to make effective and rewarding decisions [55, 67, 68]. Furthermore, exploration is critical to obtaining information to discover how the world works [67]. In this design, curiosity propels exploration, which is crucial for comprehending environments, and aims to incentivize visitors to interact more proactively with the exhibition site.

This study assesses the influence of XTR on user experiences within automated exhibitions, leveraging the allure of adventure-themed mobile games to stimulate exploration. While the presence of mobile games in museums is not a novel concept, the distinct emphasis here is on nurturing exploration and promoting self-directed learning.

Human-computer interaction (HCI) research has extensively examined the potential of mobile devices in the realm of mixed reality gaming [22, 69–74]. Yet, a notable research lacuna persists concerning the role of exploration-centric components in automated contexts.

We posit that harmonizing mobile technology with mixed reality gaming paradigms can amplify the efficacy of self-directed automated exhibitions. The overarching objective is to kindle curiosity, sustain interest, and proffer a compelling visitor experience. Our investigation delves into the way mobile platforms facilitate exploration and autonomy, placing particular emphasis on digital adventure games tailored to the diverse requirements of automated exhibitions.

To this end, we developed XTR, a geolocation-centric game tailored for the Hals Museum and Redoubt (HMR) in Denmark. This initiative seamlessly intertwines gaming elements with pedagogical content. Consequently, XTR aspires to direct users within automated exhibitions, incorporating game dynamics to encourage expansive exhibition exploration and showcase cultural heritage through an immersive digital lens.

2.1 Context: Hals Museum and Redoubt

The Hals Museum and Redoubt (HMR), nestled in the coastal village of Hals in Northern Jutland, Denmark, is a testament to cultural heritage, fortified within the ramparts of a 1600s redoubt. In May 2018, it underwent a transition from a conventional museum

Nonetheless, attaining this coveted flow state mandates intentional and meticulous design strategies. Exhibits ought to offer a spectrum of engagement avenues—be it emotional, cognitive, or sensory. When information is foisted upon visitors as indisputable fact, it can dampen their exploratory zeal. On the flip side, exhibits that fall short of visitor anticipations or skimp on interactive facets can cause curiosity to ebb, potentially derailing the transformative learning journey. Therefore, Csikszentmihalyi and Hermanson make a case for curating experiences that artfully interweave curiosity and exploration, laying the groundwork for an idyllic learning milieu [40].

1.3 Curiosity and Exploration

Curiosity and exploration, two intrinsically linked concepts, permeate a multitude of disciplines [41, 46, 49–51]. Interest, often dubbed as the curious emotion, emerges as a cornerstone of human motivation and a lens to understand personality nuances.

This kinship also finds resonance in artificial intelligence, where curiosity informs learning and problem-solving trajectories [52–54]. Exploration, on the other hand, can oscillate from a spontaneous bias towards novelty to a structured pursuit of information birthed from curiosity. In this context, encounters with unfamiliar and intricate stimuli activate a reward mechanism, championing the exploration of novelty and anchoring learning [55].

Museum-going experiences are intimately personal, sculpted by the trinity of physical, social, and individual contexts the exhibit inhabits. This active engagement traverses a triad of emotional, intellectual, and social realms. User movement patterns within exhibitions have been intrinsically linked to exploration [47, 56–58]. Different visitor archetypes reveal diverse motivations, among which stands the figure of the explorer, an archetype galvanized both by and through the prism of curiosity.

In 1969, the Exploratorium in San Francisco heralded a seismic shift in museum engagement, extolling the virtues of interactivity and play [59]. These avant-garde institutions, with their accent on experiential learning, drew inspiration from John Dewey's ethos [43, 60]. Dewey postulated that authentic learning is inextricably tethered to action [43].

The meteoric rise of technology has recalibrated the museum-going experience. Mobile, contextual learning paradigms within exhibitions influence user behaviors. As visitors evolve with growing technological proficiency, they harbor amplified expectations for immersive, digital experiences. Emerging technologies not only recast museum communication paradigms but also rewrite design blueprints. Through their offerings, visitors are ushered into a realm of technologically-mediated, novel interpretations of exhibits [12, 61–65].

Striking the balance between enlightenment and experience continues to be the north star of museum design. This research pivots towards game design as the bridge. Games, celebrated for their alchemy of blending education with entertainment, harmonize with pedagogic learning models [2, 22, 66].

Constructivist and experiential learning paradigms amplify the ethos of exploration, resonating with Csikszentmihalyi's (1990) iconic *flow* construct [48]. He contended that quintessential museum learning is a holistic affair, engaging both the mind and the body,

life. Unfortunately, the discourses encompassing enlightenment and experience often err by viewing them in stark binary [13, 14, 16, 19, 20].

Technological strides have ushered museums into an era of interactive and gamified features, spanning from intriguing digital quizzes to elaborate gaming installations. These innovations have rendered museum spaces more captivating, particularly for younger audiences adept with interactive digital mediums. Thus, the traditional museum *visitor* is now recast as a *user*, immersing themselves in enlightening experiential content [12, 21–24].

However, this pivot towards gamification and interactivity has not been universally lauded. Purists hold a torch for the time-honored, structured impartation of knowledge, relegating entertainment to the back seat. This age-old tug-of-war between enlightenment and experience remains a staple in modern museum design narratives [25, 26].

Harmonizing the educational and experiential elements is no mean feat, occasionally culminating in designs that appear contrived or fragmented. When the experiential takes precedence, the educational can feel like an afterthought, and the reverse holds true as well. These dynamics critically shape the user experience, further underscored by the burgeoning role of digital interactivity in displays.

1.2 Explorative Exhibitions

During the 1960s and 1970s, the landscape of education underwent a significant shift, with concepts of informal education gaining traction [27]. This evolution cast museums in a new light, presenting them as epicenters for informal lifelong learning [28–30]. Hein (1998) introduced a series of pedagogical models tailored for museum education, among which were the didactic expository and stimulus-response models, both grounded in traditional paradigms emphasizing preset knowledge and passive learning [31]. Conversely, his discovery framework and constructivist models championed the ethos of exploration and self-driven interpretation.

In a similar vein, Kolb's (2015) experiential learning theory revolves around a cyclical process comprising four distinct stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation [32, 33]. Both Hein's constructivist approach and Kolb's model resonate with the idea of learning as an active endeavor, punctuated by bouts of introspection. Such immersive experiences find their ideal breeding ground in interactive exhibitions, paving the way for profound comprehension and enlightenment [34–39].

Building on this, Csikszentmihalyi and Hermanson (1994) spotlighted the pivotal role of curiosity as a catalyst for museum-based learning [40]. Stimulating exhibits that ensnare the visitors' attention can elevate the experiential learning quotient. A plethora of academic investigations corroborates the intrinsic connection between curiosity and learning, underlining how curiosity simultaneously fuels and is refined by the learning trajectory [41–47]. Within the confines of an exhibition, a spark of curiosity can serve as a beacon, urging visitors to traverse the space uninhibitedly. When orchestrated adeptly, such exploration can usher in a *flow* state—a zenith of immersive learning that melds intellectual engagement with personal evolution [48].

showcases how museum technology has warmly embraced the *Bring Your Own Device* (BYOD) trend [1–3]. This shift is largely attributed to the ubiquity of personal devices such as smartphones. While adopting BYOD significantly cuts down on hardware expenses for museums, it transfers the onus of maintenance and security onto the users. Importantly, user preferences for such platforms vary depending on the context.

Our study stands out as it zeroes in on fully automated exhibition sites where no human staff is available. Even though some visitors might approach this setup with a touch of apprehension, recent strides in technology, including advancements in AI, augmented reality, and virtual guides, have aptly risen to meet the challenge. Pioneering ideas like virtual museums and telepresence robots are pushing the envelope, allowing cultural experiences to transcend traditional physical confines [4–11].

In this light, we present *Explore the Redoubt* (XTR), a mobile game specifically designed for automated venues, aiming to enrich visitor interactions. Its core objectives are to navigate, spark curiosity, and promote exploration. Central to our research is evaluating how effectively XTR functions in automated settings and its proficiency in addressing diverse individual interests.

The ensuing sections delve into the multifaceted role of technology in museums, the delicate balance between education and entertainment, and an analysis of visitor motivations and tools from a human-computer interaction (HCI) perspective. This HCI foundation played a pivotal role in conceptualizing XTR. Our concluding sections will elucidate the testing and evaluation procedures for XTR, presenting a compendium of design strategies and invaluable lessons acquired, to enlighten future design, development, and research endeavors.

1.1 Museum Discourses and HCI Research

Museums, historically celebrated for their extensive and eclectic collections, have undergone a transformation from mere cabinets of curiosity to vibrant cultural epicenters interwoven with tourism and entertainment. For practitioners in the field of Human-Computer Interaction (HCI) aspiring to make their mark in this domain, grasping the foundational tenets of museum studies is imperative [12]. This knowledge equips them to architect automated design solutions tailored for exhibition venues.

For the past two decades, the nexus of educational enlightenment and immersive experience has sat at the heart of museum deliberations [13–17]. Here, *enlightenment* delves into the pedagogical, fact-driven facet of displays, while *experience* resonates with the emotive, narrative-driven side. This intricate dance between the two profoundly molds the exhibition’s aura, determining its ability to resonate, facilitate, and guide visitors.

Yet, as museums are increasingly perceived as extensions of the entertainment sphere, curators grapple with ensuring exhibits are both informative and engaging. Genevieve Bell’s work, “Making Sense of Museums,” [18] also probed the pivotal question: should museums champion education over entertainment, or the other way round? While the broader narrative in museum studies echoes this bifurcation, a contingent of scholars champions a more integrative model—melding enlightenment and experience, instead of compartmentalizing them. When dissecting museum encounters, it’s essential to regard them as distinctive, standalone events, offering respite from the mundanities of daily



Exploration Games: Can Game-Guided Systems Support Users in Automated Exhibition Sites?

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Abstract. This article delves into the potential of incorporating elements from adventure games into museum exhibitions, with a particular focus on automated exhibition sites. We advocate that principles derived from adventure games can adeptly bridge the two primary expectations of exhibitions: *enlightenment* and *experience*. Exploration-based games, such as *Explore the Redoubt* (XTR) crafted for automated venues, enable users to fulfill both these objectives. XTR, conceived to address the prevailing research voids, integrates game mechanics into the automated exhibition environment, enhancing visitor motivation and engagement. It harnesses interactive digital mediums to present cultural heritage in a relaxed, informal manner.

Existing research scarcely touches upon the design of experiential learning games developed for automated sites, which encompass both indoor and outdoor displays. Our methodology contemplates the transformation of visitor conduct at exhibitions, morphing them into avid knowledge seekers. We challenge the adequacy of current user experience models in portraying exhibitions striving to provide both enlightenment and an immersive experience. Consequently, we introduce a framework for museum interactions that deeply engages users, urging them to define their exploration trajectories, seamlessly fusing enlightenment, and engagement. Our study is set in a 17th-century redoubt where initial observations indicated greater outdoor engagement compared to indoor spaces. This observation fueled our initiative to amplify indoor visitor participation.

After testing XTR with 30 participants and employing a combination of observations and interviews, we derived key insights on designing digital exploration games that seamlessly combine enlightenment and engagement. We conclude with three design strategies to enhance visitor curiosity and exploration.

Keywords: Cultural Heritage · Mixed Reality Game · Exploration-Based Learning

1 Introduction

Museums are progressively transforming into knowledge playgrounds, merging game-based elements with mobile technologies to intertwine education and entertainment. The journey from 1950s analog audio guides to today's sophisticated multimedia devices

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issue along with some infographics that would spark discussions within the traditional teaching method. Instead, we now have a concept of a VR game that has game-like elements, which on a subconscious level teaches the student to be more action-driven in securing a sustainable future. Furthermore, the students expressed how working with and creating learning material is highly motivating for self-educating on the given subject.

We believe that the VR-game has the ability to contribute to teaching about sustainability as a supplementing tool to the traditional teaching method. The VR-game contains age-appropriate learning, inspired by the curriculum the teachers are teaching from. The goal is to spark conversations around sustainability, in- and outside the classroom. Discussions about how to act in a sustainable manner to prevent some of the presented climate issues in the VR-game. Based on our research, we can see an expressed need for learning materials that helps teachers concretize and visualize a complex topic as such. By implementing motivational elements such as feedback- and progression systems in the game, showing the students that action can make a difference.

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insight into how many different sources of CO₂ pollution they already are familiar with, as well as their level of reflection about what the future may hold.

37% of Danish school students answered in a survey that they worry about climate change in such a way that it affects their everyday life (Ritzau 2023). These numbers show that just over a third of the students worry about their future. When children and young people are regularly made aware of the climate crisis, for example in the media, and they hear and see that the planet is beyond saving, they lose hope and become afraid (Ritzau 2023). There must be given space to these concerns, but students must also gain a sense that they can do something to influence climate change. Therefore, it's important to focus on sustainability and teach students about it in school. Epinion (2021) stresses the importance of making sure proper educational tools about sustainability are available. This is where our VR-game comes into play. We already knew the learning potentials from visualizing and simulating experiences from higher education. Letting elementary school students put on VR headsets in order to visualize a complex concept such as sustainability and climate issues, proved to be a potent educational tool. To ensure the connection between the individual, content, and context, we used transformational play (Barah et al. 2011) to turn their input about climate change into gaming experiences that potentially could transform into values that the students could carry into the real world.

Sustainability is a topic you hardly can avoid hearing about. The students are no exception. Discussing sustainability in the workshops, seemed to peak their interest even more when paired with designing a game around the topic. We initially asked ourselves; *“How do we support the students in expressing their ideas and perspectives?”*. DBR is already very user-centered, as phase one is all about collecting data, not only through existing research but also through talking to users and other creators of similar work. Then the testing phase ensures the validity of the design by testing out different iterations with the user-group. Pairing this method with PD, giving the users, the students, a voice and influence in the overall narrative and design of the game – meant that we could efficiently incorporate their inputs and ideas directly into the game, backing it up with our own theoretical framework through DBR. Furthermore, it created a sense of ownership for the students as we progressed and they could see the changes being made, inspired by their own contribution from one workshop to another.

7 Conclusion

Our findings indicate that the PD approach combined with the LAB and intervention phase of DBR in our study are viable methods for projects centered around user engagement and cooperation. The co-designing role of the students has been significantly influential for the game development process. The students were considered experts in their own domain, allowing them to share their ideas and perspectives in a semi open boundary environment. Furthermore, we made sure to give them all equal opportunity to be heard - both verbally, in writing and visually, by drawing. We can also conclude that the visual representations of the students' ideas have been significant in both how the game looks, and how the content is presented.

Without the involvement of the students, we believe that the VR game would have been a more traditional learning game, focusing on the visual representation of a climate

6 Discussion

In this section we will discuss our findings from the previous section with focus on students' perspective on learning games, Co-designing game development and Sustainability in education.

Our findings show that students' perspective has had a major impact on the design of the VR-game, particularly the students' drawings. Involving young people in the design process comes with a necessary discussion about the extent of which they participate, how much influence overall they will have and how we interpret and analyse the inputs that we get. In this study, we position ourselves as the game design literate, inquisitive about their experiences and curious about how they view learning games and by the end, ask if they have any ideas for the game at hand. Every idea or thought on learning games was paired with questions like *"Can you see that working in our game, in some capacity?"* or *"Is there any way we can brainstorm a way to incorporate exactly that game element you like into the game and add a learning element to it?"* - really trying to push the abstraction level of their creative thinking. Giving the students the focus on what the boundaries were and guiding their idea generating stages in the right direction, is something Khaled & Vasalou (2014) deemed crucially important.

Khaled & Vasalou's (2014) research presents two major challenges involving children as co-designers. One being the lack of domain knowledge and the other a general deficiency in game-design literacy. In the beginning of the first workshop, we had very open-ended boundaries set for what the children could contribute with. Big game elements like open-world multiplayer ideas that would require too much time playing the game, pushing the balance between a conventional entertainment game and a learning game, way too much to the entertaining side or just plain out of theme with the game. We procedurally started to set more boundaries, yet still leaving some space for new takes on how the game could completely pivot - within the sustainability theme. As previously mentioned, we wanted to allow their abstract thinking to be free, which led to ideas such as stopping the plastic from ever going into the river in the first place, by setting up recycle stations - which in turn showed a lack of domain knowledge of how the infrastructure of the country didn't permit such a thing. Then the idea of having a futuristic narrative came in, tying the whole objective of the game together with a classic game element (Istiono & Waworuntu 2021).

Khaled & Vasalou goes into detail how children do not possess any game design literacy, on the contrary, we learned that the children had already had some experience, designing their own learning game through a project in Minecraft. They were well intune with most of the elements from the intrinsic skill atom's table, such as action, goals, rule settings etc. (Deterring 2015).

Knowing we wanted to make a VR game about sustainability meant for elementary school students we asked our first research question; *"What climate issues interest students and how do we create and communicate content to students that motivates more sustainable action and awareness?"*

Our findings shows that the students in general are interested in taking care of our planet. We must recognize that their domain knowledge of sustainability and climate change exceeds our expectations. Even though they have only started to receive education in sustainability the same year as our study. Their current domain knowledge gives an

processing it in the end. Continuing the conversation about CO₂ emissions, the forest fires were brought up by a student. Which in turn led to another conversation about deforestation, or the industry cutting down an inconsiderable number of trees, destroying the homes of animals and ecosystems. At this point, after discussing the different potentials of creating awareness about other climate problems, coming back to the world we were focusing on, the plastic pollution, it seemed to have sparked new ideas for the game.

One student asked why the game wouldn't be about stopping the plastic from getting into the ocean in the first place, instead of trying to pull it out. This of course sparked a conversation about the logistics and economics in building a disposal facility in a small village in a third world country. This would also spark a new idea that involved a recycle-grenade that would blow the plastic into fragments that could be used to upgrade the players weapons/tools to defeat the plastic boss (Fig. 4). One student compared it to Minecraft, a building game where you harvest/destroy natural resources like trees or iron 'blocks' to gain its materials to ultimately upgrade your tools, armor, or weapon that you wield.

5.4 Game Development

In the developing process we have tried to include as many of the students' suggestions as possible. Based on all the students' ideas and suggestions in both workshops we have transformed the first prototype from workshop 1 to an actual game with game-elements. We have used Deterdings' (2015) model of 'Schematic of a skill atoms' to develop the foundations of the VR-game in the shape of goal, action, challenge, objects, rules, feedback, and motivation.

The goal of the VR-game is to save the planet and learn about sustainability in a fun way. The VR-game is based on a narrative. Action is when the player travels back in time to save the planet. The player is faced with four portals, each with its own climate change. The challenge is to solve these climate changes by playing various minigames e.g., in the portal about plastic, it's the minigames about removing and fighting trash. To add learning into the VR-game there are some objects in the form of facts and information about sustainability and the world's current and future climate problems. The player can use this knowledge to answer a quiz in each portal and take the knowledge out in the real world. The game also contains rules, such as limitations to where the player can walk, which objects can be interacted with and how many pieces of plastic you need to destroy before completing a mini game. VR is not a very social technology as you can, in most instances, only experience it on your own. Our VR game is to be considered as more of a conversation starter and generally speaking a supplement to the existing sustainability teaching. This allows the students to experience the game for short amounts of time and then have a discussion about the content presented with their peers and teacher. With the theme of a handful of NPCs we introduce gives the player a feeling of being a part of something bigger and helps to motivate the player to play the VR-game. The competent feeling is induced by the rewarding elements and feedback of the VR-game in the form of high score and voice-over, sound, text, and images that tell the player how a challenge has been completed.

5.3 Sustainability

To find out what climate issues interests' students we had a dialogue with the students in workshop 1 about sustainability and climate change. To our initial surprise, the students already knew a lot of things about sustainability. One even brought up Power-to-X, which is a relatively new concept involving transforming carbon monoxide into usable fuel for planes, cars, trains etc. The students shared their knowledge- and gave their inputs, about which climate changes they found important to have in a game about sustainability. During the dialogue, one of the students decided to draw portals for each of the climate change we discussed, see Fig. 6.



Fig. 6. Portals of climate change in the VR-game.

The four portals shown in Fig. 5, is a collective representation of the different climate problems that the students were interested in. From left to right, Overfishing, global warming, plastic pollution in the ocean and lastly, forest fires and deforestation. Each portal represents a new world with its own challenge, knowledge to be obtained and games to play. These four portals represent climate change issues of which the students are interested in and create more awareness on sustainability. We talked with the students about overfishing, how the coral reefs suffer, ecosystems are destroyed, and self-sustaining breeding cycles are being heavily affected by it. On the topic of global warming caused by CO₂ emissions, the students talked in great lengths about the impact the industry has on the CO₂ emission. One student went into detail about the aluminum factories, talking about the lengthy process of digging it up, washing it, melting it, and

Interviewer: Remember, we are developing an educational game. It's not a game you play at home, like you play 'Five Nights at Freddy's'.

Student 1: Why not? Why can't it be a fun game? Why can't you play it at home?

Interviewer: So, it's about making a game that we say is a game where you can shoot zombies. But we're not saying it's plastic zombies out on the sea...

Student 1: And it's a learning game... You just can't associate it with a learning game. They shouldn't think: "Oh, it's a learning game".

Student 4: That's right. When people our age hear it's a learning game, we think: 'Oh for fuck's sake'.

Interviewer: So, what I hear you say is that we can make a mixture? We can make something where there is some learning in it, but it also needs to have some game-elements from entertainment games?

Student 2: Yes! For example, mix a shooting game into it or something like that."

Extract of interview with the students in workshop 1.

This extract shows that the students agreed that learning games are boring. This made us think about how we present the learning part in the VR-game and how we can make it a fun game for the players. *"It's like if you need to give a pill to your dog and you wrap it in a piece of ham."* said one of the students, implying that if it had to have a learning component, it would have to be somewhat hidden. The conversation that followed resulted in an insight into how we could implement a narration that supported the learning component but still felt like a traditional entertainment game. Istiono and Waworuntu's (2021) research on learning vs. entertainment games also supports this initiative. Their research concludes that game-elements like rewards, challenges, character, and narration are the driving factors in why kids like entertainment games better (Istiono & Waworuntu 2021). Having a format such as a beginning, a middle and an ending, allows the player to immerse themselves in the game better. Which is why, by the end of workshop 2, we started co-designing a narrative about a time traveling character (the player) and a time machine (Fig. 5).



Fig. 5. The VR-games time machine

Interviewer: A boss?

Student 6: YES! (Laughing). With health-bar and XP!"

(Extract of interview with the student 6 in workshop 1)

Based on the drawing and the conversation with the student we implemented the character into the VR-game. The drawing and the implementation are shown in Fig. 4. When we presented the group of students to this new addition, at the second workshop, it was like a shift in their perception of what was possible to implement for the next iteration.



Fig. 4. The Plastic Boss from one of the minigames

5.2 Learning Design

During the workshops we also discussed the learning aspect of the games and how the games could be used to teach others about sustainability and climate changes. According to the students, games are a good way to learn, because they are doing something they are interested in and therefore learn more according to themselves.

“I like to play games, so when I play a game and learn in the process, I will learn more than if I did homework in books. I’m not interested in books. I’m interested in games.” Quote of a student.

One of the students brought up the negative connotations concerning classic learning games during workshop 1. The following transcript is a snippet of the conversation we had about it.

“Student 1: Zombie apocalypse! That’s when the plastic runs wild!

Student 2: Plastic apocalypse!

Student 1: There is a main quest about saving the earth and a lot of minigames where you must sort and remove the plastic as fast as you can. [...] Like Fruit ninja where you chop plastic bottles over. Then you must fight against the plastic!”

(Extract of interview with the students in workshop 1).

This shows how the students have helped co-design the VR-game using their experiences. Student 1 describes an idea for the VR-game’s plastic world inspired from a video game he knows - Fruit ninja. In this way the students use their knowledge and experience to co-design a game they want to play.

“Student 5: He is from the future, so he knows that’s going to happen and he is coming to stop it.

Interviewer: Okay, so the avatar has a time machine?

Student 5: No, it’s yourself. You’re the person who knows what’s going to happen and that’s why you travel back in time. You know that if it continues the world will end.

Interviewer: It sounds like the whole basis of the game.

Student 5: Yes, all of it!

Interviewer: Then it’s just before you must start on a planet where everything has gone wrong.

Student 5: Yes, a backstory! You start in a world where things are destroyed and there are disasters everywhere. Then you press on a button and go back in time. [...] He has lost his family. The only job he has is: Save the World! So, what he saw in the future, it is not going to happen.

Interviewer: The starting scene could be a time machine that just spawns in the middle of a desolate place where there’s no green anymore and the scene is drying up. It’s not a nice place to be in. [...] But just before it’s all 100% over, he manages to take the time machine and go back and save it all.

Student 6: Uh! Uh! Uh! (Starts to draw a time machine)

Student 5: Because he already knows what is going to happen. He’s from the future!”

(Extract of interview with the students in workshop 2)

While some of the students immediately shared their ideas and thoughts about their idea’s others were more reserved. During one of the observations a student drew a plastic monster. The student did not initially say much, but viewing the drawing and asking questions regarding it helped to get him talking and helped us to understand his ideas.

“Interviewer: It’s that an avatar?

Student 6: No

Phases in the thematic analysis	Description of the analysis procedure
1. Familiarising with the data collection	Read and re-read the transcribed the data, notes, and drawings from the workshop.
2. Generating of initial codes	Looking for noteworthy details of the data noting initial notes and codes noteworthy details of the data notes and codes.
3. Searching for themes	The code is organised into initial themes.
4. Reviewing themes	The themes from phase 3 are reviewed. Some of the themes may have to split up while others remain as they are.
5. Naming and defining themes	The themes are named and defined by identifying the essence of each individual theme.
6. Producing the analysis paper section	Analyses the theme selected by relating them to the research questions.

Fig. 3. Phases in the thematic analysis (Braun & Clarke 2006)

5 Findings

The workshop sessions provided insights about what interested students and what they knew about sustainability and climate change. It also offered opportunities to discuss these topics and introduce more knowledge to the students laying the foundation for the focus on sustainability in development of the game. Often these conversations would be initiated from questions about the student's drawings. In the following section we will provide examples of how the game design process facilitated conversations and learning opportunities about sustainability. The examples also show how design artifacts such as the drawings helped support these conversations.

5.1 Game Design and Student's Perspective

In workshop 1 the students use their experiences with video games to come up with their take on which game-element they find fun, interesting, and motivating and which ones they think should be included in the VR-game.

inspiration from when preparing the educational material for their classes (Gyldendal's digitale læremidler, n.d.).

After having play-tested the VR-game in workshop 1 the students further developed the VR-game with their ideas and perspectives. In the co-designing process, we provided paper and pen which allows a more creative expression and ensures that all our participants could contribute on their own terms (Clark 2017; Spyrou 2011). Some of the students' drawings were in such detail and perfectly within our intent and theme of the game, that we transferred them directly into the game.

Throughout the idea-generating phase we positioned ourselves as researchers, curiously asking into their experiences with sustainability, games in general and more specifically into their ideas and inputs to the VR-game. We tried to minimize the inherent power-balance between student and researcher by working on a relative and trustful bond between us (Spyrou 2011). To understand their ideas and perspectives we asked the students a lot of questions, which helped us narrow down what game designs/elements motivates and encourages them to play VR games and video games in general. Filtering through the many ideas presented by the students in workshop 1, we had to establish a few criteria as to what could be made in our given timeframe. In the exchange process of all the students' ideas we looked at; What is possible and not possible in the program we use? How does the learning content and game-elements interact? How does the VR-game become fun for the students and how can teachers see opportunities in using the VR-game in their teaching? This way we sets up clear boundaries for what could be designed. Based on the students' ideas, perspectives, and drawings we developed a second prototype.

In workshop 2 the students play-tested the second prototype. The second prototype consisted of a world selection screen with four different climate issues (Overfishing, global warming, plastic pollution in the ocean and forest fires and deforestation.), two minigames to the plastic world in the VR-game and a questionnaire to test their knowledge and the ability to roam relatively free in our virtual world. They also further developed and co-designing some new ideas and inputs to a third prototype such as a main story about a time traveler from the future who must travel back in time and make a difference for the climate to save the earth. This narrative has been included in the third prototype.

4.3 Data Collection and Analysis

During the workshops we would take notes and record the discussions between the students. Furthermore, we keep the different design artifacts created through the session for inspiration. The recording of the sessions got transcribed and categorized through the thematic analysis by Braun & Clarke (2006). We use the six phases in the thematic analysis to process our data (Fig. 3).

By using the thematic analysis, we have pointed out three overall themes in the data collation. These themes are Game design and students' perspective, learning design and sustainability. The notes gave us context clues from certain times in the recordings, describing certain emotions or reactions the co-designers might have had to playing the game.

educators who have experience with implementing VR as a teaching method. Based on the empirical data, we designed a prototype to play-test and further develop through PD and a continuous semi-structured interview format with our co-designers. In phase two of the DBR-model the lab-phase we utilized the workshop method to further gain insight into our target demographic audience.

We invited six 7.th grade elementary students from a local school into two workshops. This target audience were selected because at this age the students start to address issues about sustainability and climate problems through classes such as biology, geography, and physics/chemistry. Furthermore, young people in the age of 13–14 years can think abstractly, logical, critical, and problem solve (Kuhn 2009). The goal with involving the students were to support them, through co-designing a VR-game, to express their ideas and perspectives on sustainability and climate problems, as they know which games and game-elements capture their interest and motivation.

In workshop 1 the students play-tested the first prototype which was more a VR experience more than a VR-game, we developed it inspired by interviews with two educators who are experienced in applying VR in their teaching. We used CoSpaces Edu (2023) to create the prototype and future iterations of the game. In Fig. 2 a collage of the first prototype is shown where the students were presented with plastic issues. We chose not to add any game-elements to the first prototype because we wanted the students' ideas and perspectives on how we could create a game they would want to play.



Fig. 2. The first prototype of the VR-game.

When developing a learning game, it is important to consider how the game can ensure learning, motivate, and simultaneously challenge the player (Deterding 2015; Hanghøj 2019). To ensure the learning element in the VR-game we use Gyldendal's educational platform. This platform is a well-known tool for Danish teachers to draw

4 Research Design

4.1 Methodology

A combined approach of DBR (Christensen et. al. 2012) and PD (Sanders & Stappers 2008) is employed, recognizing the need for iterative development while ensuring our users' involvement and providing them the right tools to voice their opinions and knowledge.

DBR uses a four-phase model we use to frame the whole process from start to finish (Christensen et. al. 2012). We start by looking at the context for our study, based on research and the empirical material gathered from our interviews. Going into phase 2, the "LAB-phase", we use the collected data and chosen relevant theories from phase 1 to develop our design-framework and principles. Next, we start making the first prototype of our VR-game, ready to be tested in phase 3. The intervention phase is testing the feasibility, effect, and legitimacy of the prototype design (Christensen et. al. 2012). Taking notes on how to improve the design and looking out for new research or theory to support the redesign. The final phase, reflection, is an analysis of how robust the design is put up against other contexts (Christensen et. al. 2012). Does the design relate to a more general use, other than the context intended.

PD presents two ways of user involvement - co-creator and co-designer (Sanders & Stappers 2008). Co-creators are typically involved in everything from the beginning until the end of the design process. They co-create any backend coding, framework or UX for example. The co-designer-role is characterized as an advisory role, meaning we as the creators will extract ideas and design-oriented inputs from our co-designers (Sanders & Stappers 2008).

In this study start we by using the DBR to get knowledge around the subject and to create the first prototype of the VR game based on theory and initial research. In the workshops we applied a more PD-oriented approach where the students as co-designers further developed the VR-game.

The PD method was introduced to help the students express their thoughts and viewpoints regarding their concerns related to climate issues in the workshops. We decided, given the age and limited time we had with the students, that we would introduce them to the design process as co-designers in the LAB phase of the DBR-model (Christensen et. al. 2012). Co-designers' primary role in the process is sharing ideas and thoughts, and in our case, visual representations with the developers (Sanders & Stappers 2008). Based on the students' experiences, perspectives, and ideas, we developed the second prototype, which the students in the intervention phase tested and evaluated.

4.2 Workshops

In this study we used two workshops to gain insight about the students' ideas, perspectives, and experiences. The aim of the workshops was to engage the students in sharing knowledge and creative problem solving (Ørngreen & Levinsen 2017). This as part of a co-designing process of a VR game that could effectively communicate content to motivate sustainable awareness and action. Both workshops were built on the DBR-model. In phase one we collected empirical data from existing research and interviewed two

gameplay feel autonomous, challenging within reasonable difficult and emphasize the need for a common actionable goal to ensure a sustainable future. We chose to make a VR game as the sense of presence in VR enhances the first-hand experience of the game, and thus provides the foundation for knowledge-transfer to the real world (Winn & Windschitl 2000). Furthermore, VR can provide opportunities for supporting the students' learning effect, their motivation, engagement, and concentration (Holly et al. 2021; Hu-Au & Lee 2017). This gives the students some control to define their own way of learning (Holly et al. 2021; Hu-Au & Lee 2017). Giving the player a sense of autonomy in the decision making of the game is key to keep them engaged and explorative. Autonomy ensures that every decision made, leaves a feeling of responsibility and ownership (Ryan & Deci 2000). Since VR appeals to more than one sense, it also attracts a broader group of student types. Students learn by developing and interacting with the content, then reflecting over their own learning. Holly et al. (2021) points to virtual labs, designed for active learning, as helpful in teaching students about complex subjects in a playful manner. Feeling competent is not only about always being able to solve the task at hand, first try. It is about having a baseline feeling that you can do it if you put your mind to it (Ryan & Deci 2000). Making sure that the player is being fed positive affirmations, reassuring their competency, will in turn leave the user feeling competent and thereby motivated to face the presented challenge.

To support transformative play and to strengthen the game development we also use Deterdings (2015) model of 'Schematic of a skill atoms' (Fig. 1), which describes the challenge model and a list of game-elements that are key to in developing a game. The challenge model is a visual representation of what a player must go through to complete a challenge in the game (Deterding 2015). As shown in Fig. 1 the 'Schematic of a skill atoms' contain these six points:

- Goals – What are the goals to win the game?
- Actions – What can the player do to achieve the goal?
- Challenge – What challenges must the player overcome to achieve the goal?
- Objects – What objects can help the player achieve the goal?
- Rules – What algorithms and user-defined rules are in place for the player's actions to achieve the goal?
- Feedback – How is the process expressed in the game? Could be a reward.
- Motivation – How is the player's engagement and interest in exploring and continuing to play the game maintained? (Deterding 2015).

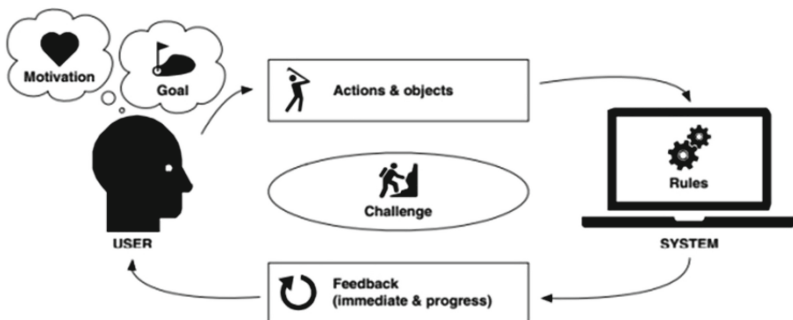


Fig. 1. Model of 'Schematic of a skill atom' (Deterding 2015, s. 314).

objectives of the game, including violent and competitive mechanics that conflicted with the very purpose of the game being designed (Khaled & Vasalou 2014).

Working with a younger audience as co-designers in their study, raised questions like; how should we incorporate children's taste in games when working in highly specific domains? What should we do when the end-users themselves do not understand the domain? How should we proceed when the game design ideas provided by children are inappropriate? (Khaled & Vasalou 2014). Throughout their studies, they came across challenges with mismatched ideas and high abstraction tasks showing that the co-designers needed knowledge of both domains and a basic level of game-design literacy.

The co-designers displayed active participation by generating numerous ideas to tackle the game design challenges presented (Khaled & Vasalou 2014). While Khaled & Vasalou's (2014) analysis did not emphasize idea quantity, the workshop showcased the co-designer's engagement through their eagerness to surpass the given tasks.

PD introduces fresh possibilities for both serious game designers and players. Drawing on experiences with established PD methods for game design ideation, Khaled & Vasalou (2014) formulated an innovative PD approach to guide ideation, aligning with the core concerns of serious games – domain expertise and procedural (Khaled & Vasalou 2014). Their findings lead to three pivotal considerations for involving children in PD for serious games. Children demonstrated optimal co-design participation during the intermediate phases of game design. In the initial design phase, when domain content and pedagogical theory were undecided, the open-ended boundary objects Khaled & Vasalou (2014) employed lacked the required theoretical framework to assist participants in devising specific and applicable ideas. Conversely, the more focused boundary object employed in subsequent workshops triggered inventive concepts that aligned with the game's educational goals (Khaled & Vasalou 2014). The attributes of boundary objects employed in PD for serious games should be assessed considering their role in supporting and inspiring ideation. In the later stages of the design process, designers are better positioned to create boundary objects that encapsulate the essential theoretical foundations and scaffolding to empower children in generating impactful ideas (Khaled & Vasalou 2014).

3 Theoretical Approach to the Game Design

To theoretically support the students' ideas and the game development of the VR-game we use Barab et al.'s (2011) theory about transformational play, to create a connection between content, person and context in the VR-game inspired by real climate issues. With transformational play every experience in the game change something inside the player, which the player can take into the real world (Barab et al. 2011). In that way the students can take the knowledge and experience about sustainability into the real world and hopefully use this knowledge to make a difference for climate change. With the introduction of Ryan and Deci's (2000) self-determination theory (STD), we aim to ensure that the students feel competent to act as co-designers, autonomous in their decisions and having a feeling of being involved in a greater good, being a part of something bigger. STD also translates into the game design as we strive to make the

2.2 Students' Perspectives

To develop educational tools about sustainability that can help support students in believing that their actions matter and motivate them towards such behavior, we propose including students in the design process.

Often in the past, scholars and researchers in the field of educational research have not sought young people's perspectives (Joerdens 2014). However, young people are no longer considered mainly as research objects, but rather as people with their own opinions and capabilities of offering advice about their lives (Lundy 2018). When studying a students' perspective and social participation, it does not suffice to discuss the topic from an adult's point of view but also from participation and the lens of the student's perspectives (Karlsson 2020).

Therefore, we argue that it is relevant to focus on the concept of participation when studying the students' climate issues interest and how we can co-design a VR game that effectively communicates content to motivate sustainable awareness and action.

In line with the UNs Convention on the Rights of the Child (Lundy 2007; United Nations 1989), young people have the right to have a say, and to have their opinions considered, when decisions that affect them are made. Students' perspectives can strengthen the information about the topic being studied because they can provide new knowledge and different views from those of adults (Biggeri et al. 2018). Listening is not only about the spoken words but also listening to the students' creative ways of expressing their views and experiences (Clark 2017). The students are experts in their own life and that is why we can't assume to know their answers (Clark 2017). Warming (2019) describes an inherent challenge of getting 100% access to a students' perspective as we cannot feel their emotions or be inside their thoughts. Listening, taking notes, and transcribing the spoken word comes with an inherent interpretation problem. Their perspective will always be a representation of our interpretation of what they are trying to express (Warming 2019; Warming et al. 2023). Thus, to ensure that the perspective of the students is directly included we suggest a participatory approach where the students participate as co-designers in developing a game about sustainability through participatory workshops. The approach is inspired by the findings from a study about PD for serious game development by Khaled & Vasalou (2014).

2.3 Participatory Design and Game Design

The PD design method aims to cooperate with the people who, in one way or another, is going to be the end-user of the product. PD gives various ways of which the co-designer or creator, can represent their peers, skills, and unique insights (Bødker et al. 2022). PD has been used in a variety of design processes, serious game-design being one of them. Khaled & Vasalou (2014), two researchers in the game development industry, present observations made from attempting to apply existing PD methods of brainstorming and storyboarding to their serious game-design process with children.

In the study they asked children to play an early game prototype and to create storyboards of potential game narratives. While children provided a wealth of information that was used to improve the game, they often proposed ideas well beyond the learning

2.1 The Need for Sustainability Teaching Materials

Research shows that teachers worldwide find it important to teach sustainability, but many teachers find it difficult despite a rising importance in both international and national policy (EducationWeek 2023; Epinion 2021; Shift Insight 2022). Epinion, a Danish consulting company that also covers a wide range of research fields, did an extensive research project back in 2021, surveying 1.396 elementary school teachers who taught any science-, culture, language, or practical subjects, on how they incorporate sustainability teaching into their classes (Epinion 2021).

The Epinion (2021) report shows that 66% of the teachers agreed that sustainability should be a part of the curriculum. Furthermore, agreeing that students should have the belief that their actions matter and that the teaching should focus on motivating such behavior and create discussions about what sustainability is (Epinion 2021). More than half of the teachers in question took inspiration from the UNs 17 world goals for a sustainable future (Epinion 2021). They would also look for sustainability media content to illustrate the complex subject, such as movies or documentaries.

As part of a pre-study, we initially conducted two semi-structured interviews with educators who are experienced in applying VR in their teaching. In the interviews the educators indicated that; teachers besides consuming illustrative content, would use hands-on teaching such as; going to a local water stream to research ecosystems or catch and cut up a fish to see the microplastics. These examples indicate that teachers would go unconventional routes to teach the subject.

The Epinion (2021) report also shows that 77% of the teachers in question expressed difficulties with incorporating sustainability in their classes expressing how it is very time consuming to prepare materials. They felt inadequate in their abilities to teach such a complex subject. Epinion (2021) stresses the importance of making sure proper educational tools are available. The Epinion (2021) report shows 30% of the teachers felt the same.

Shift Insight (2022), a consulting educational market research and analysis company, sent out a survey in 2021 to 500 teachers in the United Kingdom asking how they felt about teaching sustainability. The results from Shift Insight (2022) varied a little from Denmark, having 85% of the teachers agreeing on sustainability is an important subject to teach and only 55% of them think they haven't received sufficient training or tools to do so. EducationWeek (2023), a news and information company about education, recently published an article, in collaboration with the Smithsonian Science Education Center, about the lack of sustainable awareness and teaching in schools, in comparison to countries like France, Canada, India, and Brazil. Although the consensus about the importance of sustainable teaching was similar to the mentioned countries – the competency and knowledge to teach was at 37% compared to 78% in Brazil (EducationWeek 2023). Allocating time to teach about sustainability also proves to be an issue as only 20% manage to do so. Compared to 84% in France or 80% in Brazil (EducationWeek 2023).

deforestation, and overfishing. We have been particularly focused on two world goals for this study. Goal 12, which describes the need for ensuring sustainable consumption and production patterns and Goal 13, which describes five actionable targets to strive for in order to secure a sustainable future (Global Goals 2023). However, environmental and climate issues are not something that can simply be fixed today, but a future problem for many generations to come (Global Goals 2023). Taking action now is one thing, but making sure future generations have the right tools and insights into sustainable living and climate issues is another important responsibility. Research shows that many teachers find it hard to teach a complex topic like sustainability (Epinion 2021). Epinion (2021) iterates that developing supplementing teaching materials about sustainability is very important.

This paper initiates an exploration that centers on elementary school students' engagement as co-designers in a project focusing on designing a Virtual Reality (VR) game.

Acknowledging the demand for more teaching about sustainability in the elementary school system, led us to design and develop a VR game about environmental issues, bringing in the students as co-designers. Research shows that VR and games in education opens for new possibilities in supporting students' learning, motivation, engagement, and immersion (Holly et al. 2021; Hu-Au & Lee 2017; Istiono & Waworuntu 2021). In contrast to this, research made by Istiono & Waworuntu (2021) shows that learning games are generally less attractive than classic entertainment games. Consequently, we need to implement classic game-elements such as rewards, challenges, characters, and a narrative to keep the students interested in and motivated to play the VR-game but how do we do this in a way that appeals to school students and at the same time introduce them to climate issues?

In this study we apply a Participatory Design (PD) (Sanders & Stappers 2008) method approach where 7th grade students are involved as co-designer in a process of developing teaching materials focusing on sustainability. Using the PD methods, we allow the students to become co-designers so they can influence the content of the VR-game in a way that relates to them and their reality. Pairing the principles of a user involvement method such as PD with the iterative procedural framework of Design-based research (Christensen et. al. 2012), gives us the necessary tools to ensure a solid design, derived from prototyping, theorizing, and collecting empirical data.

In this study we aim to answer the following research question:

- What climate issues interests' students and how do we create and communicate content to students that motivates more sustainable awareness and action?
- How do we include students in a co-design process of a VR game with focus on how to support the students in expressing their ideas and perspectives?

2 Background

In the following section we will briefly summarize research about user involvement through PD, game design, student's perspectives, sustainability teaching and VR to provide the necessary background to understand our study and co-design workshops.



Co-designing VR Game Content for Sustainability Education

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Abstract. In this paper, we introduce a study about primary school students who participate as co-designers in a design and development process of a Virtual Reality (VR) game about sustainability. Utilizing methods like workshops and focus group interviews, as part of a participatory approach, we seek to gain a unique insight into the students' own perspectives and experiences with videogames and how the student actively could integrate their interest and knowledge in sustainability into the game design as co-designers. We initially conducted two semi-structured interviews with educators who are experienced in applying VR in their teaching. Following the interviews with the educators, we facilitated two workshops with six 7th grade students. The students play-tested our initial iteration of the VR-game and afterward helped co-design two new iterations. Having them influence the development of the VR-game, with the notion of "by students for students", showed increased motivation towards developing the VR-game as co-designer. Categorizing, analyzing, and reviewing their spoken word in transcriptions, written, and drawn down ideas - resulted in several applicable ideas and materials for further development of the game. Our findings showed how the students expressed interest in contributing to the sustainability premise of the game. We realized how vast their knowledge was on the subject to begin with, which only led to more in-depth discussions on what contributes to the changing climate. We believe that, based on feedback and the theoretical framework, that the VR-game serves as an efficient educational tool, that can help facilitate conversations about sustainability.

Keywords: Sustainability · Participatory Design · Game Design · User involvement · Design-Based Research

1 Introduction

For the past decades there has been a rising preoccupation with the state of the climate and the environment. The United Nations (UN) has set up seventeen world goals to overcome climate issues and to create a better world for future generations (Global Goals [2023](#)). The world goals serve as a call-for-action and point out exactly where the needs for action are to reduce environmental and climate issues such as global warming, plastic pollution,

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Regarding instructional design, it is evident that the difficulties encountered and the participants' perceptions regarding VR provide important guidance for instructional design, considering initial adaptation to the tool, teacher training, equipment availability, valorizing interaction elements and available resources, emphasizing realism and immersion, ensuring safety and comfort when using the equipment, session duration, communication and collaboration, as well as clear content transmission. Additionally, the importance of promoting alternative plans to address technical failures that may compromise the learning experience is evident.

Furthermore, it was concluded during the application phase of the instructional design model that it presents some difficulties in its completion. It was noticeable that the process is time-consuming, and without careful and prior reading of the explanatory guide, it becomes difficult to understand what needs to be defined at each point. This situation highlights the need to improve the process, as it may lead to user abandonment. Therefore, it was found that it would be more appropriate to include sections with auto-fill suggestions and concise explanatory messages.

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6.2 Second Test Session – May 26th

Time: Students expected the virtual reality class to be designed for short periods, and their expectations were met. This indicates that the instructional design was efficient in providing an experience that fit the available time and the content approach.

Immersion and Realism: Students positively evaluated the immersion and realism of the virtual reality learning experience with the Oculus equipment. The use of virtual reality as an instructional tool proved to be effective in creating an immersive experience for the students.

Communication and Collaboration: Students reported ease of communication and collaboration during the class, although one participant mentioned a lack of opportunity to interact with other participants beyond written communication (whiteboard). This information highlights the importance of designing activities that encourage interaction among students in virtual reality and provide clear opportunities for communication and collaboration.

Clear Transmission of Content: Students considered that the information was transmitted clearly and comprehensibly during the class. This reveals the importance of considering clarity in information transmission when planning VR training moments.

Comfort and Practicality: Students positively evaluated the use of virtual reality equipment in terms of comfort and practicality, with only a few difficulties mentioned in adjusting the device. This suggests the need to pay attention to device adjustment to provide a comfortable experience for students.

Again, the technical issues and limitations mentioned by students, such as low Internet speed and the inability to share slideshows, also have implications for instructional design. These technical issues need to be addressed and resolved to improve the effectiveness of instructional design in virtual reality.

In summary, the information gathered in the second session provides important guidance for instructional design, particularly regarding time planning, immersion and realism, communication and collaboration, clear transmission of content, and comfort and practicality.

7 Conclusion

A prototype of an Instructional Design for virtual learning environments using Oculus Quest 2 has been developed and tested. The instructional design model considers aspects such as defining learning objectives, content selection, activity sequencing, instructional principles, methodology, resources, student activities, and assessment. Tests and experiments were conducted with students and teachers to identify difficulties and constraints in the use and implementation of the model.

Preliminary results show that participants faced initial difficulties in adapting to the Virtual Reality environment, particularly with motion controls. However, they expressed interest in participating in VR classes due to interactivity and educational potential. Participants reported interaction with virtual elements, a sense of immersion, and the perception of the reality of the VR experience.

6 Discussion

6.1 First Test Session – May 5th

Considering instructional design, it is possible to group the students' responses to obtain insights for improving the prototype. This enables identifying patterns and areas that need enhancement, resulting in a more efficient instructional design that is tailored to the identified needs in the use of VR.

Initial Adaptation: Participants mentioned the need for an initial adaptation phase to the VR environment and motion commands. This highlights the importance of providing an adequate introduction and clear instructions to help students become familiar with the environment and commands before starting the learning activities.

Teacher Training with the Hardware: Some responses indicated that participants faced difficulties related to using the motion commands and buttons. Therefore, it is important to ensure that teachers are properly trained in the use of the equipment and familiar with the functionalities of VR. This will enable them to provide support and guidance to students during the lessons.

Availability of the Equipment: Some responses mentioned concerns about the availability of the equipment, especially the Oculus headsets, for all students. The instructional design should take into account the available and necessary materials to ensure that all students have the opportunity to participate in the classes and benefit from the learning experience.

Interaction and VR Resources: Participants highlighted the interactivity and the ability to interact with virtual elements as attractive aspects of the VR experience. The instructional design should explore and incorporate these interaction features in a meaningful way, creating engaging activities and promoting active student participation.

Realism and Immersion: Participants described elements that contributed to the sense of spatial immersion, such as the ability to see their own hands and the realistic response of virtual objects. When designing VR lessons, it is important to consider these aspects and strike a balance between spatial immersion and the need for effective learning, taking into account the current limitations of the technology.

Safety and Comfort: Some participants mentioned concerns about dizziness when using the headset. The instructional design should consider safety measures and ensure that students are instructed on the proper use of the equipment, as well as provide adequate breaks and rest opportunities to minimize any discomfort. Therefore, the timing of the sessions should take this aspect into account.

In summary, the information gathered about the difficulties faced and the participants' perceptions regarding VR provide important guidance for instructional design. These insights help in planning learning experiences, considering initial adaptation, teacher training, equipment availability, interaction, and immersion, as well as student safety and comfort.

5.2 2nd Session

The second session, focused on the application of the Instructional Design model in session planning, was planned to take place within the VR environment, specifically in a class on Instructional Design using the Meta Horizon Workrooms platform.

Regarding the responses, although there were few (4 answers), from the students to the questionnaire conducted at the end of the session, they indicate that their expectations regarding the VR class were generally met. They expected a tool to be used for short periods, and the activity carried out corresponded to their predictions. They also considered the environment immersive and satisfying in terms of spatial immersion and realism.

Regarding communication and collaboration during the class, students had ease in communication and collaboration, although one participant mentioned not having the opportunity to experience communication with other participants solely through the whiteboard (a resource available in the environment for writing their ideas about the exercise).

Regarding the quality of the content presented, students considered that the information was conveyed clearly and comprehensibly, without highlighting any specific points for improvement.

In terms of comfort and convenience, the virtual reality equipment was evaluated as practical and comfortable, with only a few difficulties mentioned regarding adjusting the device. However, no significant physical discomfort was reported.

However, the low expressiveness of the questionnaire responses may indicate that there were technical issues that affected the smooth development of the VR session. Issues such as low Internet bandwidth for three simultaneous devices, connectivity difficulties among participants in the same scenario, and the inability to share slideshows may have interfered with the students' experience. These technical aspects need to be addressed and improved to ensure a smoother and more satisfactory experience.

Additional observations collected through observation notes were also provided, revealing the difficulties encountered, including issues with writing on the virtual whiteboard (*"If you don't touch the table, the writing isn't continuous"*), auditory aspects (*"Confusion between sound in the Oculus and reality"*), technical glitches (*"Connectivity problems"*), time difference between speaking in reality and hearing in the other headsets, and additional comments regarding the practicality of the classes (*One student preferred in-person classes as Virtual Reality can generate distractions*).

In summary, students' expectations regarding the VR class were mostly met. Students appreciated the immersion, clarity of conveyed information, ease of communication and collaboration, and the comfort and convenience of the equipment. However, it is necessary to address technical issues to ensure a more consistent experience and improve interaction among participants.

Furthermore, in line with the context, participants were asked if they were interested in participating in classes using Virtual Reality. The responses demonstrated a general interest in attending classes through virtual reality, mainly due to interactivity, dynamism, and the potential to make classes more engaging and interesting. However, it was also highlighted that certain aspects of learning may be better explored in the real world. Examples: *“I want to learn in a different way.”*; *“Because they will be more dynamic and interesting classes.”*

Concerning the observation notes with participants after the VR experience, similar to the responses to the questionnaire, the main difficulties encountered were in using motion controls and interacting with virtual elements: *“[He/She] had difficulty in grasping the objects.”*; *“Difficulty in clicking the button because [he/she] doesn’t think it is well explained how to click.”*

The need for necessary precautions to ensure user safety and comfort was also emphasized, e.g.: *“[He/she] was afraid of getting dizzy but wanted to keep participating in the Oculus constantly.”*

Regarding interaction with virtual elements during the VR experience, participants described a variety of actions and reactions. They explored the virtual space, danced with the animated character from the tutorial, used virtual objects such as weapons, and interacted with elements present in the scene. Example: *“[He/she] enjoyed dancing with the character, and everything was intuitive.”*

Considering the sense of spatial immersion in the VR environment, participants reported feeling immersed primarily due to the ability to move around, the quality of sound, and the ability to see their own hands. Interaction with virtual objects also contributed to the sense of spatial immersion: *“[He/she] felt immersed, what [he/she] saw, the sound, and seeing the hands.”*

Regarding the realism of the VR experience, participants considered the virtual room as the most realistic aspect. They mentioned the realistic response of the characters to movement, the ability to see their own feet, and the possibility of grabbing objects as elements that contributed to the realistic experience. However, some participants also pointed out that overall, the VR experience still does not fully compare to reality. Sample comment: *“The realistic objects and environment made [me] feel immersed.”*

Concerning participation in VR classes, participants showed interest and emphasized interactivity, dynamism, and the potential to make classes more engaging and interesting. However, they also highlighted the importance of certain classes or sections being conducted in the real world.

Regarding precautions necessary to ensure the safety and comfort of participants in VR classes, some participants mentioned concerns about possible dizziness and the need to use the headset with care. The importance of not immediately sharing with students the fact that they will be using the headset was also mentioned: *“It was very interesting, and [he/she] enjoyed exploring this aspect as a teacher.”*; *“It would be interesting to participate, and [he/she] would like to participate when [he/she] becomes a teacher.”*

8. Realism of the VR Experience
9. Precautions Necessary for VR Classes

In these themes, challenges faced by participants during the virtual reality tutorial session were identified, including difficulties with motion control and other technical issues before the implementation of instructional design. Additionally, students' interest in participating in virtual reality classes was assessed, as well as difficulties reported after the VR experience in interviews, highlighting the interaction with virtual elements and the sense of immersion and realism during the experience. Precautions necessary for conducting VR classes were also discussed.

2nd Session:

1. Students' Expectations for the Second Virtual Reality Session
2. Communication and Collaboration During the Virtual Reality Class
3. Quality of Presented Content
4. Comfort and Convenience
5. Additional Observations Collected through Observation Notes

In the second session, the themes focused on students' expectations for the virtual reality experience, including communication and collaboration during the class. The quality of presented content and the comfort and convenience offered by the technology were also evaluated. Furthermore, additional observations collected through observation notes addressed various issues, including technical difficulties and students' preferences for in-person classes.

5 Presentation and Analysis of Results

5.1 1st Session

During the Virtual Reality orientation session (1st session), students were asked several questions, with a focus on issues such as *"Today, during the VR headset orientation, what were the biggest difficulties you encountered?"* The aim was to identify the main challenges faced while getting acquainted with the VR headset. Regarding the primary difficulties encountered when using motion controls during the VR experience, participants mentioned initial adaptation, understanding the commands, and locating the buttons *"I had difficulty only at the beginning to familiarize myself with the controls, especially in knowing where the buttons were"*. Some participants also expressed difficulty in grabbing specific objects.

Regarding the question *"Thinking about the implementation of Instructional Design and a class in this environment, what previous difficulties do you identify?"* The responses pointed to challenges related to initial adaptation, teacher training, equipment availability, interaction among participants, and proper utilization of VR resources. Some examples: *"Initial adaptation and training for the teachers"*; *"I think the only difficulty could be the space-number of children relationship"*.

- 2) *How did you interact with the virtual elements during the VR experience? What were your actions and reactions?*
- 3) *How immersed did you feel in the VR environment? What elements contributed to that sensation?*
- 4) *In what aspects was the VR experience realistic? Were there any aspects that you found unrealistic?*
- 5) *How would it be for you to participate in a VR lesson, and what precautions would be necessary to ensure your safety and comfort?*

During the second session, where the Instructional Design model was applied in session planning, the aim was to verify the applicability of the model and assess its effectiveness by observing participants' interaction with the VR environment and collecting feedback through a questionnaire administered via a form. The questionnaire addressed the following aspects:

- 1) What were your expectations regarding the VR lesson before participating? Were these expectations met? Why?
- 2) In terms of immersion and realism, how would you evaluate the VR lesson experience? Did it meet your expectations? If not, what did you expect to be different?
- 3) Considering interaction with the virtual environment and other participants, how would you evaluate the ease of communication and collaboration during the lesson? Were there any aspects that could be improved in this regard?
- 4) Regarding the quality of the content presented in the lesson, do you consider that the information was conveyed clearly and comprehensibly? Was there any specific point that could be improved for better knowledge assimilation?
- 5) Thinking in terms of comfort and practicality, how do you evaluate the use of virtual reality equipment during the lesson? Did you experience any physical discomfort or obstacles that interfered with your experience? If so, how do you believe these aspects could be improved?

The questionnaires and records allowed obtaining information about participants' experiences, perceptions, challenges faced, and suggestions to enhance the use of VR in education. The collected data will be analyzed to make adjustments and future improvements to the instructional design and implementation of VR lessons in Higher Education Institutions (HEIs).

During the sessions, a content analysis was conducted using various themes to gather valuable insights [18]:

1st Session:

1. Challenges with the Virtual Reality Tutorial Session
2. Difficulties with Motion Control Usage
3. Challenges Prior to Instructional Design Implementation
4. Interest in Participating in Virtual Reality Classes
5. Difficulties Reported after the VR Experience (Interview)
6. Interaction with Virtual Elements During the VR Experience (Interview)
7. Sense of Immersion in the VR Experience

strategies used in the field. The second session was conducted Horizon, as previously mentioned.. The session consisted of a theoretical exposition of Instructional Design and a practical segment where participants planned a session for primary education on the water cycle, based on the instructional design model.

The plan for this second session was to conduct the entire session exclusively in the Virtual Reality environment, using the headset (Fig. 2).



Fig. 2. Horizon Class Experience. Source: authors' photos.

4 Methodology

To test the prototype of Instructional Design for Virtual Reality, a qualitative research methodology was adopted, involving data collection through questionnaires and observation notes with distinct purposes and questions across the sessions. The first session had 14 participants, while the second session had 9 participants.

The research aimed to achieve the following objectives:

1. Identify the applicability of the developed Instructional Design model for Virtual Reality.
2. Evaluate the participants' experience concerning immersion, interactivity, and usability of the Virtual Reality environment.
3. Gather participants' feedback on their Virtual Reality experience.

The data collected through questionnaires and observation notes were analyzed to gain insights into the effectiveness and user experience of the Instructional Design model within the Virtual Reality context.

During the initial session to familiarize participants with virtual reality, the goal was to observe and record the initial difficulties they encountered when adapting to the VR environment. For this purpose, a questionnaire was administered to collect feedback from participants about the first session, focusing on immersion, interactivity, interest, and educational potential of VR. Informal interviews were also conducted after the VR experience, addressing the following questions:

- 1) *What were the main difficulties you encountered when using the motion controllers during the VR lesson?*

in a game, while others experienced a “visit to the bottom of the sea,” which is one of the scenarios developed within the REVEALING project. As there were only two headsets available, additional activities were organized to ensure everyone remained engaged. Three activities were thus conducted: an Escape Room to explore other scenarios developed for the project, a Digital Puzzle featuring the project’s logo, and an Augmented Reality Exercise that incorporated objects and concepts related to the project. Each group participated in one of these tasks.

The session concluded with participants using Quizalize⁴ to vote again, this time linking terms to their correct associations. A debate was also initiated with the students to gather reactions and feedback about the experience. Finally, the participants completed a form on Survio⁵ to share suggestions and feedback about their experience.

It’s important to note that this session was conducted in person, focusing solely on the use of Virtual Reality (VR) technology for the “First Steps” tutorial⁶ and the presentation of an example virtual room in VRChat⁷ (Fig. 1).



Fig. 1. Oculus Quest 2 Experience. Source: authors’ photos.

In this second session, the plan was for the entire session to take place exclusively in the Virtual Reality environment using the headset. The second session took place on May 26, 2023, after the participants had become familiar with VR. In this session, approximately 9 participants were divided into groups of 2 and allocated 15-min sessions each.

During this session, the prototype of the Instructional Design model, described in Sect. 3.2, was used to support instructional design.

The objective of the session was to present the basic concepts of Instructional Design, explore its importance in creating educational materials, and demonstrate techniques and

⁴ Quizalize is an online platform that provides teachers with tools to create engaging quizzes and assessments for students (<https://www.quizalize.com>).

⁵ Survio is an online survey and questionnaire platform (<https://www.survio.com>).

⁶ “First Steps” oculus tutorial (<https://www.youtube.com/watch?v=tLsAnrsXoxA>).

⁷ VRChat is an online social platform that allows users to create and customize their own avatars and worlds, and then interact with others in virtual reality. (<https://hello.vrchat.com>).

the design of the environment, the agents or actors involved, the sequence of tasks or activities, and the monitoring process of teaching and learning. The planning matrix for the sessions includes various elements such as topic, phase/time, location, duration, learning objectives, key content/principles, methodology, resources, student activities, and assessment.

Overall, our Instructional Design model is drawing from various theoretical frameworks and models, to support effective planning and execution of VR lessons, promote student engagement, and facilitate meaningful learning experiences.

3.3 Prototype Testing Sessions

The prototype testing sessions were scheduled for students of the ICT and Basic Education course of the bachelor's program in Basic Education at the University of Aveiro. The class consisted of 22 students, with 14 attending the first session and 8 in the second session.

ICT and Basic Education is an optional course offered as part of the program. The course takes place in the 2nd semester of the 3rd year, and the tests were held during the academic year 2022/2023. The course spans 13 weeks, with half of the classes conducted in person and the other half delivered through synchronous videoconference sessions using the Zoom platform. Additionally, there are asynchronous activities on the LMS Moodle and the Seesaw platform², practical workshops with guest speakers, and autonomous work sessions. The course awards 4 ECTS credits.

The objectives of this course are to develop digital skills and pedagogical knowledge in students by involving them in a project that integrates ICT in Basic Education. The teaching methodology includes Project-Based Learning (PBL), where students are divided into groups and work on projects that integrate ICT into the curriculum of Pre-School Education or Basic Education. The groups present their projects in stages, submitting different parts as they progress. In the academic year 2022/2023, the course had 22 students, including 4 Erasmus students, forming 6 teams. The teams were given the freedom to choose their project theme and determine the level of Basic Education to which it applies (e.g. primary, grammar, lower high school, ages approx. 6–14).

The first session, held on May 5, 2023, lasted for 90 min and had the following objectives: (1) familiarize students with the REVEALING project and the application of Virtual Reality in educational contexts; (2) provide hands-on experience with Virtual Reality using the Oculus Quest 2 headset; (3) engage in activities related to virtual learning scenarios and gather suggestions for their creation; and (4) initiate discussions about the virtual reality experience and reflect on its potential.

The session commenced with a Kahoot³ questionnaire to assess participants' knowledge and understanding of key project concepts. A brief presentation of the project followed, covering the main points. The practical part involved dividing the class into small groups and focusing on the use of the Oculus Quest 2 headset. Some participants engaged

² The Seesaw platform revolutionizes interactive and engaging learning experiences for students, educators, and parents through its innovative digital tools and communication features (<https://web.seesaw.me>).

³ Game-based learning platform (<https://kahoot.com/what-is-kahoot/>).

3 Context

3.1 REVEALING Project

This study was conducted as part of the REVEALING project, which falls under the Erasmus+ initiative (Erasmus + Project REalisation of Virtual rEality Learning Environments (VRLEs) for Higher Education). The primary objectives of the project are as follows, and this led us to attempt developing an instructional design model for immersive virtual reality:

- Design and implement VRLEs (Virtual Reality Learning Environments) tailored to the needs of Higher Education Institutions (HEIs).
- Create pilot lessons using virtual reality (VR) technology.
- Develop a comprehensive guideline manual on the utilization of VRLE resources.
- Establish a VRLE Resource Directory to facilitate the incorporation of VRLE-compatible resources in HEI education.
- Empower teachers and students in HEIs to utilize innovative educational approaches with VR technology.

3.2 Prototype of the Instructional Design Model

These prototype tests aimed to identify any missing aspects or shortcomings of the instructional design model, through the observation of potential difficulties or constraints, as well as advantages expressed by participants when using VR in education. Our prototype of an Instructional Design Model comprises several planning phases, which include defining learning objectives, establishing the learning scenario, designing the environment, and selecting agents or actors. The session planning matrix encompasses various elements such as phase/time, learning objectives, key content/principles, methodology, resources, student activities, and assessment. The model draws on other theoretical models and frameworks to assist in defining these components, as follows: Bloom's taxonomy [10] guides the definition of learning objectives, while the methodology incorporates various pedagogical methods to support the learning process, including expository, demonstrative, active, and collaborative methods [9, 11, 12]; Merrill's instructional principles [13] are utilized to support instructional design; for the assessment component, models such as Boud's [14] "sustainable assessment" or the PRACT model from the Portuguese Open University are followed, proposing tasks that consider students' attitudes, knowledge, and skills/competencies, as well as the feasibility of their implementation by teachers [15]. We also considered previous studies, particularly the Standards of the Association for Educational Communications & Technology for Instructional Design in distance education [16, 17]. These standards encompass 10 key elements for learning design models, crucial to ensuring the effectiveness of the teaching and learning process, including Purpose, Assumptions, Sequence, Activities, Resources, Application of new learning, Ongoing/formative assessment, Reflection, Independent learning, and Evaluation.

Furthermore, to complement this Instructional Design model, the definition of learning scenarios is considered a distinct element compared to traditional teaching within the context of Virtual Reality. A learning scenario encompasses decisions related to

This work reports on the test of a prototype Instructional Design model for Virtual Reality, using a qualitative research methodology. The tests aimed to identify any missing aspects or shortcomings of the model, through observation of potential difficulties or constraints, as well as identifying its advantages as expressed by participants when using VR in education. The study was conducted in a Higher Education undergraduate program, specifically in the ICT and Basic Education course. It consisted of two sessions, the first aimed at familiarizing students with Virtual Reality, the second providing an immersive classroom experience using Horizon¹.

Data collection was carried out through questionnaires and observation notes, with the intention to: (1) identify the applicability of the Instructional Design model developed for Virtual Reality; (2) evaluate the participants' experience regarding immersion, interactivity, and usability of the VR environment; (3) obtain feedback from participants about their experience with Virtual Reality.

2 Background

Virtual Reality, an image processing technology that allows users to experience being surrounded by a synthetic environment [1, 2], i.e., feeling perceptually “immersed” in a computer-generated world, has been applied as a pedagogical tool, with various rationales such as to enhance learning outcomes or providing context and focus [1, 3].

In these virtual reality environments two complex phenomena co-occur: learning and immersion [4]. Immersion is understood as more than just the visual perception of feeling present amidst a space. It also refers to a state of deep mental involvement (or absorption) with a narrative or an activity. In the context of learning, immersion can thus help students in multiple ways: they can benefit from the spatial interaction modalities, they can find meaning from the immersion with the narrative, and they can focus and engage more deeply via the immersion with their activity potential (“agency”) [4].

Instructional design aims to ensure the quality of instruction, making it more efficient, effective, and less challenging. It involves activities such as needs analysis, defining learning objectives, establishing evaluative goals, and determining specific outcomes for successful learning. Instructional design bridges learning theories with the practice of developing instructional systems [8, 9].

The introduction of such immersive learning environments has brought new challenges and concepts, including the ability to assess the relevance and purpose of digital information, the need for communication skills in digital environments, skills to create multimedia content and programming, the ability to adopt security and sustainability measures in data protection, and the ability to solve problems and adapt digital resources for different purposes [5], raising questions about the application of instructional design in this context, as it provides guidance to teachers on how to develop and optimize the learning process [6, 7].

¹ Social virtual reality collaboration software environment (<https://forwork.meta.com/horizon-workrooms/>).



Instructional Design Model for Virtual Reality: Testing and Participant Experience Evaluation

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Abstract. This study aimed to test an Instructional Design model prototype for Virtual Reality (VR) in Higher Education. A qualitative research methodology was used, employing questionnaires and observations for data collection. The research had three main objectives: (1) to identify the applicability and effectiveness of the VR Instructional Design model, (2) to evaluate participants' experience with immersion, interactivity, and usability of the VR environment, and (3) to obtain feedback from participants about their VR experience. The study involved two sessions. In the first session, participants were introduced to the VR environment, and their initial adaptation difficulties were observed. Informal interviews and a questionnaire collected feedback on immersion, interactivity, interest, and educational potential of VR. The second session indicated the need for revisions in applicability and ease of use. Based on student feedback, session planning should consider initial adaptation, teacher training, equipment availability, interaction elements, resources, realism, immersion, safety, comfort, session duration, communication, collaboration, and clear content delivery. Providing alternative plans for technical failures is essential. Despite these challenges, participants expressed interest in participating in VR sessions and activities.

Keywords: Virtual Reality · Immersive Learning · Instructional Design · Higher Education

1 Introduction

The use of Virtual Reality (VR) as a teaching tool has sparked great interest in the field of education due to its potential to create immersive and interactive experiences. However, to ensure the effectiveness of this technology in pedagogical practice, it is essential to develop suitable Instructional Design models that align with the principles of instructional design and educational technology standards.

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Fig. 8. Result of the use of JSON file.

6 Final Remarks

Part of a larger project dedicated to assisting visually impaired individuals, the primary objective of this initiative was to create a tool that simplifies the augmentation of image datasets. This was achieved by isolating clothing items within images and organizing them into a comprehensive database. Subsequently, this enhanced dataset formed the basis for training new algorithms crucial to the development of a tool tailored to the specific needs of the visually impaired community. These algorithms are instrumental in the identification and extraction of vital features. They are an integral part of an application designed to improve the daily lives of blind individuals by providing them with independent clothing management. This, in turn, significantly impacts their self-esteem, allowing them to make confident and autonomous choices about their attire. Ensuring that the blind community can access detailed information about their clothing, ultimately empowering them to take greater control of their wardrobe and, by extension, boosting their self-confidence. This was achieved by extracting garments from images and cataloging them in a database. Subsequently, this enriched dataset served as the foundation for training new algorithms integral to the development of a tool catered to the needs of the blind community. These algorithms facilitate the identification and extraction of essential features to enhance the user experience. The results obtained show that our model obtained precision levels on a spectrum from 75.7% for jackets to 99.6% for shoes. The system can store and retrieving all the information regarding an object's segmentation on a database and creating JSON files that will facilitate the augmentation of datasets.

In the scope of future work, one of our primary goals is to develop an autonomous learning system that continuously improves itself by recognizing new categories and learning from its mistakes. Additionally, we plan to adapt the current user interface into a web-based platform. This transition to a web page will enable seamless access and interaction with the tool across various devices and platforms, promoting greater accessibility and convenience for users.

For each element with a matching category on the database, a new folder is created with the filename, and a copy of the original image and the corresponding created JSON file are stored inside this folder.

When the user clicks the “Delete Incorrect Data from Database” button, an entry widget is generated, accompanied by a “Confirm Delete” button (as shown in Fig. 7). Within this entry widget, the user can input a specific filename associated with the data they wish to remove. Upon clicking the “Confirm Delete” button, the application initiates the deletion process, removing the data corresponding to the provided filename from the database.



Fig. 7. Interface modifications when the “Delete Incorrect Data from Database” button is used

The JSON files created through both the “Select Files” and “Select Category” processes follow the same approach. The resulting JSON file serves as a valuable input for annotation tools. By using this JSON file in conjunction with the original image, users can efficiently annotate images, simplifying the data augmentation process. The result of applying this can be observed in Fig. 8.

Leveraging the JSON file and employing annotation tools presents a more efficient and streamlined solution. The JSON file conveniently contains all the necessary information, such as object segmentation points, enabling annotation tools to automatically generate the data annotation.

In contrast, opting for the alternative approach would entail resorting to manual point-by-point annotation, a meticulous and time-consuming process. This method would require identifying and marking each point or region within the image, which can prove to be highly laborious. Moreover, as the complexity and scale of the dataset grow, the effort and time invested in this manual annotation process would increase exponentially, potentially becoming impractical or unfeasible.

Furthermore, a JSON file is generated. The information is saved on the database. The original, bounding box, and object only images and class are displayed on the interface, as can be visualized in Fig. 5.

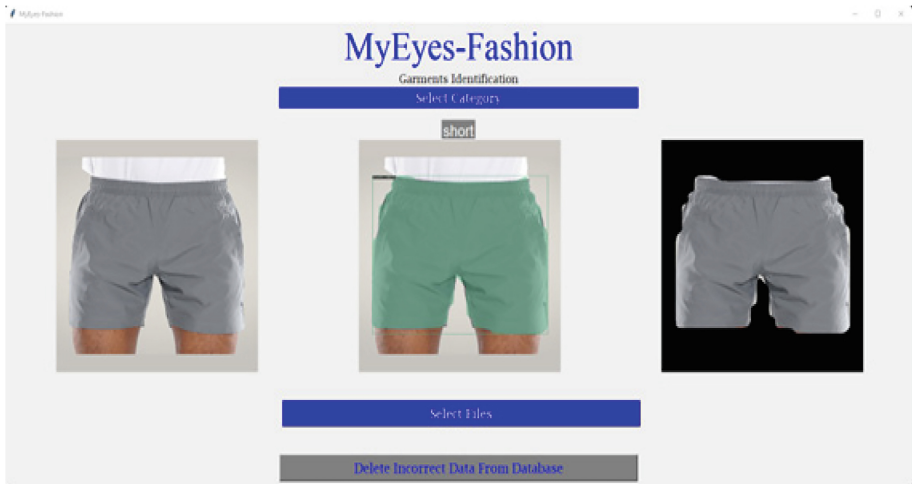


Fig. 5. Interface displaying the detected class and, from left to right, the original, bounding box, and object only images

When the user clicks the “Select Category” button, a drop-down menu appears, presenting all the available garment categories for selection. From this menu, the user can choose a specific category of interest, Fig. 6. Upon selection, the application creates the corresponding folders containing the original images and JSON files associated with that category.



Fig. 6. Interface displaying the drop-down menu for category selection.

image retrieval as select input images for processing, and delete inaccurate data from the database, respectively.



Fig. 3. GUI main page.

When the user clicks the “Select Files” button, a pop-up window appears, Fig. 4, providing the user with the option to select images. This feature enables users to choose one or multiple images from their local storage for further processing and analysis within the application.

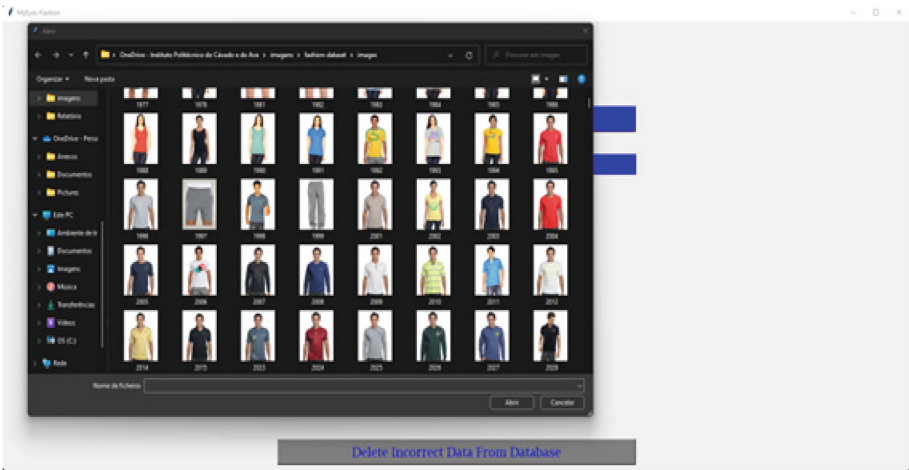


Fig. 4. Pop-up window after using the “Select Files” button.

Once the user selects files, the application processes them by identifying the category of garment detected and extracting the bounding box coordinates for each image.

stood out as the chosen one for algorithm development due to its consistently good results. It achieved a mean average precision (mAP) of 85.1%, with precision levels ranging from 75.71% for jackets to 99.63% for shoes.

Using this model we can obtain the category of the detected garment, the bounding box, and object only images; some examples of the obtained results are shown in Fig. 2.



Fig. 2. Results images. Left to right: original, bounding box, and object only images. Examples for dresses and jackets.

While not common, some confusion occurs when the input image features a woman wearing a t-shirt or a shirt, leading the model to misidentify them as a dress. Additionally, the model occasionally confuses long shorts with pants, contributing to further instances of confusion.

As the developed database serves as an efficient repository, effectively storing all the essential data required for the project, we can interact with the database and retrieve vital information. Such as:

- Detected category id;
- Detected category;
- Filename;
- Bounding Box points;
- Original Image File Path;
- Segmentation points.

By having this stored data, accessing all the necessary information to create a JSON file becomes effortless.

Regarding our interface, on the main page, our GUI incorporates three buttons: “Select Category,” “Select Files,” and “Delete Incorrect Information from Database”, Fig. 3. These buttons offer users distinct functionalities to choose garment categories for

“dress,” “jacket,” “pants,” “polo,” “shirt,” “shoes,” “short,” and “t-shirt.” Upon connecting to the database, we retrieve all items that match the selected category and create a corresponding JSON file, which is then saved alongside the original image.

Additionally, to ensure that the database only contains accurate information, an option has been implemented in the user interface. This option enables the user to delete image information based on its file name. By doing so, any incorrect detection can be easily identified and removed from the database. This functionality empowers the user to maintain a clean and reliable database by selectively removing data that may not meet the desired criteria. This way, the database remains accurate and relevant, allowing for improved performance and meaningful results in subsequent processes.

5 Experimental Results

Using the created dataset, without data augmentation, our model was trained, using the training parameters as follows: “ims_per_batch” set to 1, “base_lr” to 0.00025, “batch_size_per_image” set as 128. We aimed to explore the impact of different training iteration rounds on the model’s performance. For each experiment, we varied the number of training iterations while keeping other settings constant. The results are presented in Table 1 and analyzed to understand the effect of training duration on the model’s accuracy and convergence.

Table 1. Training model results (%) for different training iterations (7500, 10000, 30000).

Number of training iterations	7 500	10 000	30 000
mAP	77.40	80.76	85.10
mAP50	82.05	85.29	89.80
mAP75	81.26	84.25	88.56
Dress AP	76.64	76.13	76.52
Jacket AP	80.06	80.37	75.71
Pants AP	89.03	86.14	86.85
Polo AP	87.64	91.66	92.06
Shirt AP	47.20	67.97	80.00
Shoes AP	98.70	99.05	99.63
Short AP	76.86	78.20	86.70
T-Shirt AP	63.14	66.56	83.39
Total Loss	15.48	09.88	08.88
Accuracy	98.55	98.61	98.88

Observing Table 1 one can see that the model underwent training using different iteration rounds, and as the number of iterations increases, noticeable improvements were observed. Among the various iterations, the model trained with 30000 iterations

4 Methodology

To be able to extract garments from images it became necessary to develop a dataset and a model capable of semantic segmentation.

Our dataset consists of 2000 images, distributed equally amongst 8 categories of garments, those being: dresses; jackets; pants; polos; shirts; shoes; shorts; and t-shirts. The 250 images per class are split into training and validation images with ratios of 0.8 and 0.2, respectively. A mix of images from the public dataset Fashion Product Images [21], as well as pictures taken in a home environment, were used. With those collected it was necessary to annotate every image, those were made resorting to the Roboflow tool [22]. The dataset was exported under the data format COCO JSON.

On the Google Colab platform [23], utilizing the Detectron2 [24] library, as well as others necessary for image manipulation, such as OpenCV, our model was trained under various conditions. A pre-trained Instance Segmentation model was utilized, “COCO-InstanceSegementation/mask_rcnn_R_50FPN_3x.yaml” through transfer learning.

Having as an objective the ability to catalog the garments extraction data, an algorithm in Python was written, and for that we used the *psycopg2* library, to connect to the PostgreSQL [25] database. The table includes the following attributes:

- “Id” – An auto-incrementing primary key column;
- “Category Id” – A integer column that stores the detected category in integer form;
- “Category” – A non-nullable VARCHAR column with a length of 45 characters to store the category name;
- “Filename” – A non-nullable VARCHAR column with a length of 45 characters column to store the file name;
- “BoundingBox” – A TEXT column to store the bounding box coordinates under array form;
- “OriginalImageFilePath” – A VARCHAR column with a length of 300 characters to store the file path of the original image;
- “SegmentationPoints” – A TEXT column to store the segmentation points.

To allow the upload of images, the performance of object detection and segmentation, and retrieval of data from a database based on the detected categories, a GUI was developed “MyEyes-Fashion”, using the Tkinter library. The application includes a main menu with buttons to upload images for processing “Select Files”, to select a category to retrieve data from the database “Select Category” and to delete incorrect information from the database “Delete Incorrect Data from Database”.

Once the user uploads the images, our pre-trained model processes them. This allows us to acquire the detected class, the image with a bounding box and object segmentation, the predicted segmentation mask, along with the bounding box coordinates from the model’s outputs. Using this information, we can perform further processing to obtain an image that contains only the detected object, along with the contour points necessary for image segmentation. Subsequently, a JSON file is generated, and all the previously mentioned information is stored in the database.

To access the information from the database, a drop-down menu was implemented using the ‘Menu’ widget in the Tkinter GUI. The menu contains the following items:

Although garments detection systems have shown promising advancements, they continue to encounter challenges, particularly with confusion between different categories of clothing. One major contributing factor to this issue is the scarcity of high-quality garments datasets with accurate annotations. In response to this challenge came the development of this study.

3 Project Overview

The main objective of this work is the creation of a tool that allows the extraction of garments from images and their cataloging in a database to feed artificial intelligence algorithms in the identification and extraction of its features. For that reason, the tool can create JSON files and save them in a folder, along with the original image. This can be done in two ways, the inputting of images or the retrieving of data from the existing database.

Using the JSON file, we can effortlessly obtain the segmented image through annotation tools, avoiding the need for manual point-by-point annotation as the alternative method.

Thus, the system is divided into two main stages the extraction of garments from images and their cataloging in a database and the retrieval of information from the database (Fig. 1).

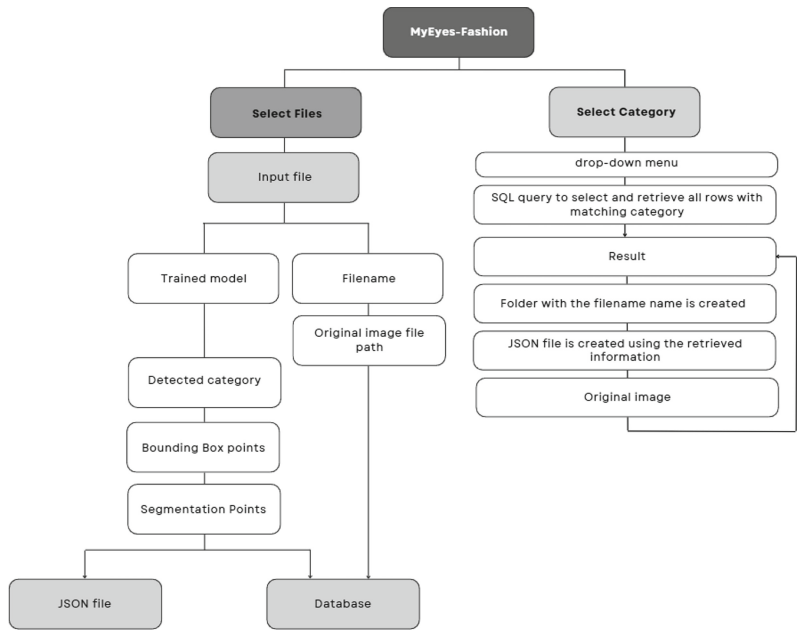


Fig. 1. Project Overview

database. Subsequently, the extracted images and tags are used to analyze the image under examination.

Using Feature Pyramid Networks, a neural network model developed by Martinsson and Mogren [14] which performs the semantic segmentation of fashion images, that can be used in conjunction with Conditional Random Fields. The model learns which body parts of the human body in which different clothing items are typically placed on and, although demonstrating good results, it shows some difficulties in distinguishing between garments used on the same body part, for example, a t-shirt and a blouse.

A model of Human-centric Clothing Segmentation via a Deformable Semantic Locality-preserving Network [15] puts together the original image and one semantically similar in the dataset, being that by having the same pose or appearance. Using a Convolutional Neural Network model based on the deformable convolutions this model can extract the non-rigid features of the clothing.

A system for garment segmentation and color classification [16] was created, given an image taken from an online fashion store - background removal is performed to obtain a binary mask. The photo type detection module first classifies the masks according to the shooting type. Consequently, according to the shooting type, both skin and additional garments and accessories are removed to obtain a clear picture of the object of interest. Finally, a garment color descriptor or HOG-based descriptors of garment shapes and textures are computed on the selected object and used for color retrieval or classification.

Using CNNs, Cychnerski et al. [17], developed a computer vision system for accurate detection and classification of clothes for e-commerce images. Utilizing the DeepFashion dataset, which contains box annotations for locations of clothes. Automatic gathering of labels resulted in an average of 83% rate of correct labels.

Kayed et al. [18], used a CNN based LeNet-5 architecture to train parameters of the CNN on the Fashion MNIST dataset, showing results of accuracy of over 98%. Outperforming both the classical CNN model and the other existing state-of-the-art models in literature.

A survey paper on Image Data Augmentation for Deep Learning [19] explains that Deep convolutional neural networks are heavily reliant on big data to avoid overfitting. Overfitting refers to the phenomenon when a network learns a function with very high variance such as to perfectly model the training data. Data Augmentation encompasses a suite of techniques that enhance the size and quality of training datasets such that better Deep Learning models can be built using them.

An article on Data Augmentation in Classification and Segmentation [20], recognizes that deep learning models may require a large amount of data to achieve satisfying results. Unfortunately, the availability of sufficient amounts of data for real-world problems is not always possible, and it is well recognized that a shortage of data easily results in overfitting. This issue may be addressed through several approaches, one of which is data augmentation. The paper examines classification and augmentation techniques in computer vision tasks, including segmentation and classification, and suggests new strategies.

From the research undertaken it becomes evident that the development of tools aimed at assisting the blind community is still below the anticipated and necessary level.

block in the progress of machine learning applications. This is precisely where the inception of an automated data augmentation tool takes center stage, holding the promise of a transformative solution. This paper outlines the development of a tool designed to extract information about clothing from images and systematically catalog them within a database. This advanced system is a pivotal component of an ongoing project aimed at enhancing the quality of life for blind individuals, particularly in terms of improving their ability to manage their clothing [1–9]. It addresses a critical gap in the project - the lack of suitable datasets that meet its specific requirements. The tool's primary purpose is to create larger and more comprehensive datasets, which serve as a critical resource by providing valuable inputs that contribute to the enhancement of algorithms utilized in the ongoing research initiative [8, 9]. This endeavor is motivated by the long-standing recognition of a pressing need within the blind community, a need that extends to the broader project, in which this tool plays a crucial role, as blind individuals have experienced persistent challenges in accessing clothing-related information autonomously [7]. As a result, the primary overarching goal is to significantly elevate the quality of life for blind users by addressing this need, providing them valuable information, and enabling confident and independent clothing choices.

The paper is structured into five sections. Section 2 covers the related work, Sect. 3 provides an overview of the project, Sect. 4 explains the methodology, Sect. 5 presents the experimental results, and Sect. 6 concludes with the final remarks.

2 Related Work

This project is associated with the My Eyes initiative [1–9], which is focused on nurturing self-sufficiency in the everyday activities of individuals with visual impairments, particularly in the context of selecting their attire.

Regarding the support of blind people in their selection of garments, we can find projects [10, 11] that can, overall, identify 11 colors (red, orange, yellow, green, blue, cyan, purple, pink, black, grey, and white) and 4 patterns (plaid, striped, pattern less and irregular). The results are given in the form of sound. In assistance to online shopping, it was developed, in 2018, the BrowseWithMe tool [12], which aids blind people gain independence and progress from passive listeners to active seekers of information. Through artificial intelligence, computer vision, and natural language processing, a product's web page is converted to a structured representation that allows the user to ask the assistant for the information he/she is seeking (e.g., price, color, description, etc.). Regarding clothing combinations, the development of a web page platform is described in [12]. This project utilizes Near Field Communication for garments identification. The clothing features are inserted manually, and it is possible to automatically identify the color of the garment. For future work, optimizations such as the automatic insertion of garments and characteristics extraction, resorting to a camera, image processing, and automatic learning algorithms, are taking place.

In the identification of garments, Yamaguchi et al. [13] propose a method of clothes analysis able to classify 53 different categories and segment each piece of clothing by exploiting super-pixels and model of flexible pieces for human pose estimation. To achieve this, the process involves retrieving similar images from the analyzed image



An Automated Tool for Creating Clothing Catalog Databases: MyEyes–Fashion

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Abstract. In the field of object identification and segmentation the development of automated dataset creation tools holds significant importance. Recognizing the necessity for abundant data, these tools serve to lighten the manual load of data organization, amplifying efficiency and enabling researchers to focus on the essence of their analysis. Integrated into a project that aims to improve the quality of life and well-being of blind people, this paper presents the steps of creating a tool capable of facilitating the data augmentation of databases to feed artificial intelligence algorithms in the identification and extraction of its features. Using a computer vision detection system, a tool was developed to identify and extract garments and catalog them in a database. For user interaction it was created an interface that allows the insertion of elements in the database and the extraction of necessary resources for easy dataset creation. In the segmentation and classification algorithm of the garments, it was obtained an accuracy between 75% and 100% in its recognition.

Keywords: Blind People · Garments · Image Segmentation · Neural Networks · Deep Learning

1 Introduction

In the dynamic landscape of machine learning and artificial intelligence, the pivotal role of training data quality and quantity in determining model success cannot be overstated. The performance of these models is intrinsically linked to the caliber of the data they are trained upon. A promising solution that has emerged is automated data augmentation – a process that not only addresses data scarcity but also amplifies a model’s capacity to generalize across diverse scenarios. As industries enthusiastically adopt these cutting-edge technologies, the demand for precise and resilient models has witnessed an exponential surge. However, this heightened demand is met with a significant impediment – the insufficiency of diverse and comprehensive datasets. The acquisition, curation, and annotation of such datasets pose substantial challenges, demanding significant financial resources and time commitments. This predicament is particularly accentuated in fields where data collection is financially demanding, time-intensive, or ethically intricate. Consequently, the scarcity of meticulously labeled, high-caliber data persists as a stumbling

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their future social educator careers. Nevertheless, we could see from the data that they showed an increased self-efficacy regarding STEM but still need to improve their STEM teaching self-efficacy.

5 Concluding Discussion

In this study, we found that the PSEs at the beginning of the course had a low STEM self-efficacy; this is supported by Prentiss Bennett (2016), who found that numerous educators “lack the efficacy for teaching integrated STEM content” (p. 68). Prentiss Bennett further emphasizes the significance of educators’ beliefs and highlights their pivotal role in achieving children’s success in the STEM fields. It aligns with the PSE’s comments on allowing children to work with science and technology, which relates to the PSEs STEM teaching self-efficacy. According to Campbell et al. (2018), although early childhood educators generally hold favorable attitudes toward STEM subjects, they lack self-efficacy and confidence in teaching them. Specifically, when it comes to engineering, Dubosarsky et al. (2018) suggest that the lack of STEM and engineering instruction can be attributed, in part, to educators’ low self-efficacy in teaching STEM. The abovementioned findings concerning PSE’s beliefs are a clear target for professional development efforts. This study shows that short courses can be beneficial and enhance PSEs’ comprehension of the significance of early childhood STEM education, strengthen their knowledge of STEM disciplines, and address potential challenges associated with teaching STEM. Consequently, these efforts positively impacted PSE’ STEM-related beliefs and practices. Nevertheless, the results of this study suggest that the use of the greenhouse emerges as a promising approach to improving the STEM self-efficacy of PSEs, especially when the science content is integrated into a STEM course. Additionally, this approach has potential value in contexts where PSEs may not have a strong STEM background. It can be challenging to generalize the data from this study because most of the research to be found is concerning pre-service teachers. However, it can give an idea of how to help PSEs gain a strong STEM self-efficacy, as this is important in relation to working with it in a pedagogical practice where they must didactically and pedagogically organize activities for others.

In this study, most of the PSEs’ interest in STEM has been sparked, and we can see that the booklet and the Google Slide, through double stimulation, triggers them to learn about STEM-related activities. Creating a greenhouse helped increase PSE’s STEM self-efficacy, and the booklet supported their learning process. PSEs gained much more confidence, and most PSEs could see how they could apply this to their future practices. The study reported here is a pilot study, giving insight into developing a teaching course that strengthens PSE’s STEM self-efficacy and their STEM teaching self-efficacy. One of the limitations of this study is the low number of participants. Although the results showed that the PSE’s STEM self-efficacy had strengthened, further study is needed to elaborate on this to supplement the findings because it only provides preliminary results that can help further develop these findings.

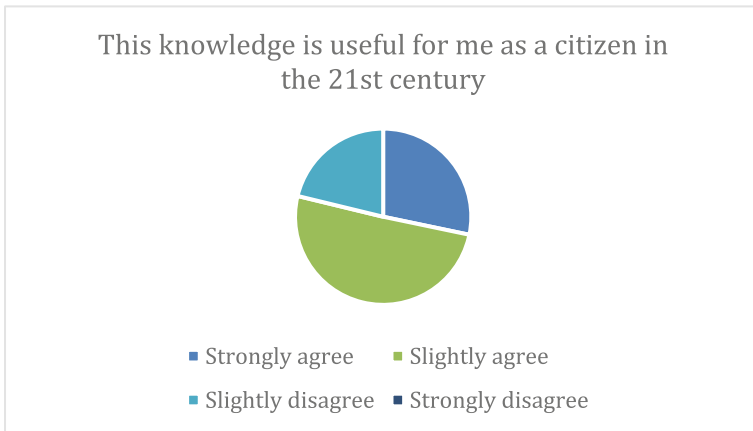


Fig. 6. Knowledge in the 21st century (0% had chosen strongly disagree)

In contrast, some PSEs could transfer it to their future practices, while others found it challenging—especially those who specialized in adults with disabilities.

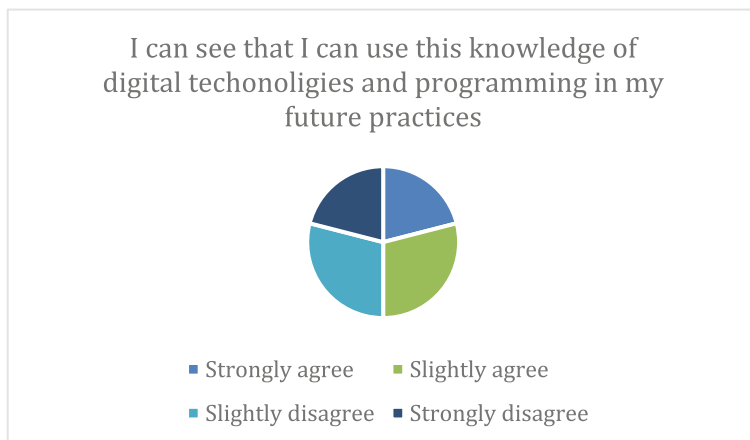


Fig. 7. Digital technologies and programming

Half of the PSEs express difficulty incorporating new knowledge about digital technologies and programming into their future practice, unlike when asked if they could use more science-related knowledge. The PSEs seem to have yet to find the relevance of working with digital technologies and programming, maybe because the PSEs worked with micro:bit, which is made for the middle school level, and only one of the PSEs worked within the school specialization. It could indicate that the PSEs about digital technologies and programming still need to be more confident to include them in their further work and need more support. Although most PSEs were motivated and engaged in the greenhouse process, they still needed help to see the relevance for themselves and

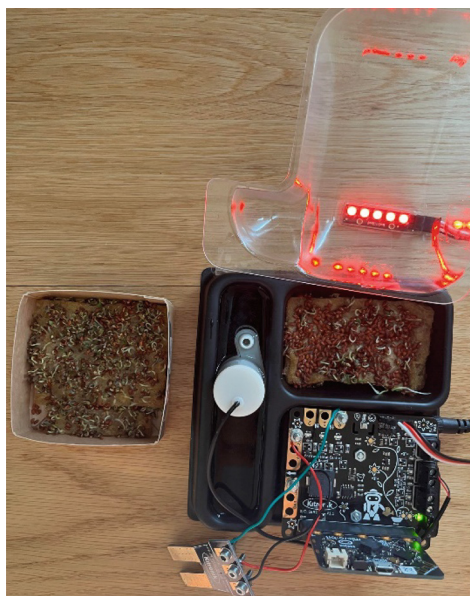


Fig. 5. Growing cress

4.4 Relevance for the Future Praxis

Over the past decade, there has been increasing recognition of the significant role that self-efficacy beliefs play in shaping PSEs' attitudes toward STEM. According to Couse Lagarón and Grimalt-Álvaro (2019), self-efficacy can configure students' perceptions about their value for STEM, affecting their interests, aspirations, and actual capacity. In this sense, self-efficacy is crucial for a positive view of STEM.

The Fig. 6 illustrate how the PSEs relate the content knowledge to 21st-century skills, with 29% strongly agreeing, 50% slightly agreeing, and 21% slightly disagreeing.

By this, most PSEs find this topic relevant to the future. One PSE supports this by writing, "I can see it being useful in the future, as it offers more digitalization of everyday life." Another PSE wrote, "I have gained a broader knowledge of sustainability." So, the PSEs can relate to STEM's science and technology parts when they refer to the greenhouse project, but it is also showing that the PSEs are beginning to be more confident in their STEM self-efficacy and their STEM teaching self-efficacy. One PSE believes that it is essential for children to learn about technology but also realizes that he must scale the activities down to an understandable level for children and that this requires some effort: "As the world becomes more and more technological, I see an advantage in introducing children to it already in kindergarten. You can easily scale it down to the children's level, and you have to learn to think outside the box."

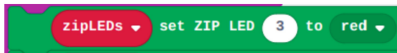
The PSEs had divergent interpretations of whether they could use this knowledge about digital technologies and programming in the future. As shown in Fig. 7, 21% strongly agree, 29% slightly agree, 29% slightly disagree, and 21% strongly disagree.

From the screen recording, we can see that the PSEs are using the booklet as a help to get out of a problematic situation. If there was a problem for instance in the algorithm, the PSEs return to the booklet to see and look for their mistake. The booklet serves as a secondary stimulus, showing the algorithm for the given output, so if the PSEs were stuck, they could find a solution in the booklet. The booklet also gives scientific knowledge about the gardening of cress and the different functions of the greenhouse. In Fig. 4. There is an example of one of the activities in task 2. In the task the PSEs are provided basic information about how to create different light and wavelength of light.

Valg af farver - blande selv med RGB

Hver neopixel indeholder 3 lysdioder, der lyser med farverne rød, grøn og blå.

I blokken



kan man indsætte blokken



i stedet for (oveni) "red", så den samlede blok ser sådan ud:



Når en farve har værdien 255, lyser farven med maksimal lysstyrke.

Når en farve har værdien 0, er den slukket.

Herved kan man selv blande sin farve.

Når alle tre grundfarver er tændt med maksimal lysstyrke, svarer blandingen til farven hvid.

Valg af farver - bølgelængde

Lys består af elektromagnetiske bølger. De forskellige farver har forskellig bølgelængde.

Synligt lys strækker sig i et spektrum fra violet (bølgelængde ca. 380 nm) til rødt lys (bølgelængde ca. 760 nm).

nm er en forkortelse for nanometer. 1 nanometer = 10^{-9} meter = 0,000.000.001 meter

Fig. 4. The code for chosen color of light and some information about light.

From the Google Slides, we could see that the PSEs were using the information about how to program the light—they were also experimenting with the type of light in different phases of growing cress. So, the booklet gives the knowledge to handle the task and strengthens the PSEs' confidence by allowing them to be successful by providing multiple and varied experiences (Keller, 1987). The Google Slide shows that PSEs also experiment with other ways to grow cress. Figure 5 shows that a group had sown cress without the greenhouse to make a comparison.

Both the booklet and Google Slides provide the PSE with satisfaction. The booklet triggers PSE's actions, so they can get help if they get stuck. The Google Slides give PSE some satisfaction when they follow the growing process of cress and test their hypotheses. As shown in Fig. 5, the group of PSEs tested if the light had any influence on the growing processes, and from their reflections, we could see that they found their hypothesis valid. Working with the greenhouse also supported PSE's mathematical understanding as they worked with data collection and different variables in the programming of the greenhouse itself.

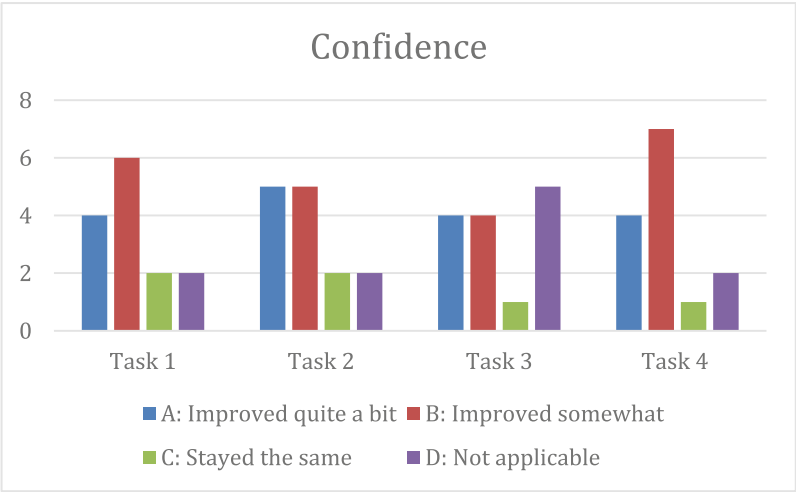


Fig. 3. PSEs level of confidence against STEM.

4.3 Hands-on Learning

When examining the theme of hands-on learning, it becomes apparent that PSEs regarded hands-on activities as a valuable component in the creation and execution of the greenhouse. The PSEs valued the hands-on activities in which they designed and implemented the greenhouse.

Zimmerman and Cleary (2006) found that facilitating the students before, during, and after STEM activities is essential to support their learning. In that light, we found it necessary to get the PSEs through a workshop where they first understand how to program the micro:bit before working on the greenhouse. The PSEs also evaluated the process after the course was ended. In the survey they completed after the courses, PSEs were asked to fill out qualitative questions about their confidence in using their new knowledge in practice. Only 4 out of the 14 PSEs stated that they would not use it after their exams. One PSE wrote, “I would not feel comfortable doing that.” The four PSEs did not participate in the workshop and only had the booklet to follow in building the greenhouse. From that, we can see that the booklet did not support PSEs who did not participate in the workshop and that they needed more scaffolding in their learning.

The booklet did not support the ARCS motivation model for PSEs who did not participate in the workshop, especially since the four PSEs did not find the work with the greenhouse relevant to their further practices. Neither did they show any confidence or motivation to acquire further knowledge. Nevertheless, one of the PSEs who has gained an interest in the subject wrote: “I have learned that we do not need to know everything but can learn with the children. I have gained basic knowledge”. One of the things that this PSE is taking from the course is a basic knowledge of STEM, and that they do not need to know everything, but that they, with a basic knowledge, can create an inspiring learning STEM environment with and for children, this is an example of how the course develops this PSE’s STEM teaching self-efficacy.

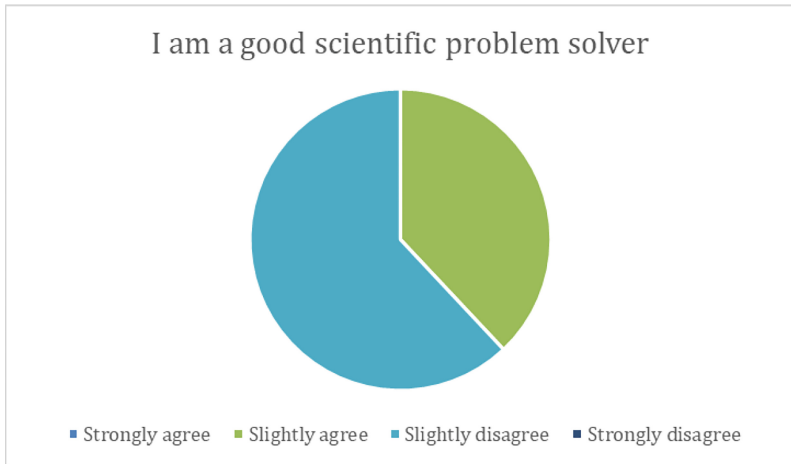


Fig. 2. Scientific problem solver (0% had chosen strongly agree and strongly disagree)

and 7% strongly disagreed. From that, it can be found that more than a third of the PSEs found the introduction to technology relevant. The next question “I do not wish to learn about digital technologies and programming” supports this. 7% wished they did not have to learn about digital technologies and programming, 21% slightly disagreed, 43% disagreed, and 29% strongly disagreed.

Concerning the paper survey, two PSEs did not complete any of the four tasks related to answer D, as seen in Fig. 3. In task 3, one group of four PSEs did not complete this task because of a time limit, which is why six PSEs are represented in answer D. Regarding answer C, which says something about the PSE not moving their confidence in their abilities, we can see that one PSE answered C on all the tasks. This PSE did not participate in the course and only had the booklet to scaffold the learning. The other PSE, who had answered C in the two first tasks, did not complete task 3 but answered B in task 4. From that, we can see that this PSE did not get much out of the two first tasks, but in the last one, she felt that she improved her capabilities. From the screen recording, we can see that this is in line with the group work, where this PSE initially did not participate in the solutions of the tasks.

We can see that the other 10 PSEs improved their abilities through the tasks as they answered A and B in all four tasks. Concerning beliefs regarding their self-efficacy, there is a consistency between using the booklet as a trigger and their capacity to work with the greenhouse. The booklet supports their work and was created to build their confidence by breaking the building of the greenhouse into smaller parts. First, they had to program the water pump, then the light, then the daily rhythm of the light, and finally, they had to program the greenhouse to incorporate all the parts.

stages of coding. A rough transcription of the screen recordings was conducted following Matthews and Cramer (2008). These rough transcriptions described the task content chronologically, providing details such as time stamps, task descriptions, and individual quotes from the PSEs. Following rough transcription, the transcriptions were coded based on the four forms of ARCS (Keller, 1987) and STEM self-efficacy (Bandura 2006).

Initially, the authors carefully read and re-read the rough transcripts, text in surveys and text in Google Slides to identify potential themes. The next level of analysis included a collaborative review of these initial codes. The focus was on preserving the diversity represented in the initial codes while formulating overarching elements or higher-level sub-themes. The next stage involved identifying quotes that resonated with the overarching themes. Subsequently, the authors reviewed these themes before defining and assigning names to them. The themes were then reviewed, focusing on the data from the three surveys. Finally, after solidifying the themes, the report's composition commenced. By employing thematic analysis with these steps, the study aims to shed light on the role of PSE's motivation and development of STEM self-efficacy, with the following overarching themes: confidence, hands-on learning, and future practices. We will elaborate on these themes in the next section.

4 Results

4.1 STEM Confidence Before the Workshop

The data showed that almost all PSEs wanted to learn more about science. Seven of the PSEs strongly agreed, five slightly agreed, and two slightly disagreed that they want to learn more about science. 57% of the PSEs strongly agreed that they were learning interesting new knowledge about science. However, when we asked the PSEs about their willingness to solve scientific problems, only 21% strongly agreed, 57% slightly agreed, and the rest chose the option slightly disagree. Campbell et al. 2022 noted that educators are interested in science and STEM but need more confidence in their ability to apply their knowledge. It is also supported by the question about whether they see themselves as good scientific problem solvers, where over half of the PSEs slightly agreed, and the rest slightly disagreed being good scientific problem solvers (see Fig. 2). None of the PSEs saw themselves as good problem solvers of STEM-related problems.

When we asked the PSEs about their confidence in digital technologies and programming, only 14% said they would be good at it. 36% slightly agreed, 21% slightly disagreed, and 29% found that they would not be good at working with digital technologies and programming.

The data shows that PSEs have low STEM self-efficacy and a lack of confidence in their work with STEM-related activities which is consistent with Campbell et al. (2018) that found that educators need more confidence in their work with STEM.

4.2 STEM Confidence After the Workshop

21% of the PSE strongly agreed that they were happy to be introduced to digital technologies and programming, 57% answered that they slightly agreed, 14% slightly disagreed,

the greenhouse pump; the second was to test LED light the third was to mix LED light and wavelength; and the fourth was putting it all together to build the greenhouse.

The booklet created for the purpose worked on the principle of double stimulation so that the PSEs first had to try to do the programming themselves and if it became too complicated, they could find a coding example in the booklet. This way the booklet acted as a second stimulus to help them further.

As part of the course, the PSEs were required to submit a Google Slide that documented their learning process and evaluated the learning content. This Google Slide consisted of screen recordings and pictures from the programming process and the greenhouse activities. The course in which this research took place lasted three weeks.

The following is the weekly outline of the course:

- Week 1: Introduction to inquiry-based science, urban farming, UN's Global Goals, and programming with micro:bits.
- Week 2: Programming of the greenhouse (self-study)
- Week 3: Evaluating the greenhouse project.

3.3 Data Collection

Before the class started, the PSEs filled out a survey that was based on the TIMMS test that tests students' mathematical self-efficacy. The TIMMS test uses a validated four-point Likert scale (Martin et al. 2016). These questions were adjusted to be related to test the PSEs self-efficacy.

Each group made a screen recording while programming for each of the four tasks. The screen recording was used to assess how they solved the task of programming the greenhouse and how they collaborated in the group. However, due to a limitation in the screencast program (Screenpal.com) the PSEs only had 15 min to record each task. This made it challenging to capture the entire process. After programming their greenhouse, the PSEs had to fill out a Google Slide in which they had to form hypotheses and justify why they had chosen a specific color of light for getting the cress to grow. After the experiment was completed, the PSEs completed another survey related to the PSEs' self-efficacy about digital technology. Those questions were, as the first survey, related to the validated TIMSS four-point Likert scale. The selected case consists exclusively of data generated through surveys, screen recordings, pictures, and self-reflections that were processed qualitatively.

After each task related to program the greenhouse, the PSEs were required to complete a paper survey about their confidence and capability to work with digital technologies and programming. We adopted the survey from Keller (1987) to get insight into PSEs' motivation on a given objective, mainly focusing on the design of the four tasks to capture the different dimensions of ARCS. After each task we asked the PSEs if their confidence in their own ability: A: Improved quite a bit, B: Improved somewhat, C: Stayed the same, D: Not applicable (I didn't do enough of the exercise to have an opinion).

3.4 Analysis

An approach based on a thematic analysis was used in this study, as outlined by Braun and Clarke (2006). The process involved transcribing screen recordings in subsequent

students with interest, challenges, and rewards, they remain motivated and develop a positive perception of their achievement. Hence, educators should consistently bear in mind the individual needs of each student and provide immediate feedback, including praise and problem-solving interactions, to reduce students' confusion and enhance their immediate satisfaction. According to the PSE's satisfaction, the educator was still available to guide and support PSEs as needed despite the booklet serving as a guide.

The application of double stimulation primarily relates to how the course is structured to facilitate the PSE's learning. In contrast, the ARCS model and self-efficacy focus more on motivation and the psychological factors influencing the PSE's learning and engagement. ARCS and self-efficacy are not directly connected, but according to Rosenzweig and Wigfield (2016), they can influence each other in the context of education. Concentrating on enhancing self-efficacy within the realm of motivational regulation introduces a new viewpoint for crafting support strategies for PSEs (Kryshko et al. 2022).

3 Methods

3.1 Participants

The PSEs studied at the University College of Northern Denmark and participated in the Nature and Outdoor Adventures electives course. 14 PSEs, 10 woman and 4 men participated in the study. Participants had completed a consent form before the data collection, and their answers were anonymized. PSEs do not typically have a strong STEM background, and many do not think highly of themselves concerning STEM. Most of the PSEs do not have an educational background in STEM-related fields but comes from the humanities, social science, or arts. In this context, it is interesting to examine what PSEs learned and what self-efficacy they have developed in a course that integrates STEM activities.

3.2 Procedure

The course consisted of face-to-face sessions with hands-on learning, using make-code.org as a coding platform, micro:bit¹ a small computer they had to program to build their greenhouse, and add-ons (water pump, LED lights, moisture sensor) to the greenhouse. The PSEs first participated in a short workshop introducing them to using micro:bit. We developed a booklet to support the PSEs in their self-study of how to program the greenhouse. The activities related to the booklet consisted of reading, viewing, and activities related to knowledge about the greenhouses and collaborative knowledge construction and reflections. The PSEs worked in groups of two to four when programming the greenhouse.

The PSEs worked on four tasks related to the setup of the greenhouse. These tasks were gradually built up with increasing complexity. The first task was how to program

¹ A micro:bit is a small, programmable microcomputer designed to teach coding to young learners.

and between students and educators to facilitate active learning. ARCS is a motivational design framework that incorporates various motivational principles and theories. These are organized into four primary domains: attention (A), relevance (R), confidence (C), and satisfaction (S). The formation of these overarching domains resulted from a classification of motivational elements sharing common attributes. The categorized domains and subcategories serve as a foundation for analyzing the aspects of learner motivation, thus assisting in formulating strategies and learning environments that motivate learners.

Attention: According to Keller (1987), capturing student's attention serves as the first and essential step in motivating them to learn. By successfully engaging their attention, the entire instructional effort can be effective. Educators should employ various teaching tools and techniques during classroom instruction to pique the interest and curiosity of working with STEM in different pedagogical activities. We created a case about how the PSE had to build their greenhouse to grow cress to capture the PSE's attention. We wrapped STEM in a well-known context by creating a project with a purpose.

Relevance: Relevance is the process of aligning instructional content with each student's individual needs and aspirations to enhance motivation to learn (Keller 1987). Students must be able to relate instructional materials directly to their career goals to capture and maintain their attention. These goals are crucial in determining whether they are motivated and inclined to sustain their focus on classroom instruction and learning. Consequently, to cultivate a positive attitude towards classroom instruction among students, educators should employ various teaching materials, instructional techniques, and activities that directly relate to learners' past experiences, existing knowledge, current interests, future expectations, and career aspirations. This approach ensures that the instruction remains relevant and meaningful to the students. In this course, we first linked to the work with kids and STEM activities, and by that, we focused on food cultivation, a topic that PSEs could relate to in their daily lives.

Confidence: Confidence can be defined as students' positive expectation of success (Keller 1987). The lack of confidence may prevent students from actively participating in the learning process. However, when students can envision positive learning outcomes, they tend to feel at ease and confident in their learning journey. In other words, the level of challenge presented should align with students' acceptable difficulty range, and the anticipation of success encourages them to persist in reaching their learning goals (Vygotsky 1978). Conversely, they may lose interest in the instructional learning process if they encounter challenges beyond their comfort zone and need more confidence in success. Therefore, to maintain the confidence of PSEs during the work with the greenhouse, educators should offer tailored support to individual student's needs, such as instructional assistance and access to relevant learning tools. We created a booklet to scaffold and support the PSEs to create confidence. The booklet used the strategy behind double stimulation (Vygotsky 1978) to help the PSEs out of situations in the learning design where they could not go further or lack confidence.

Satisfaction: The last element in the ARCS motivational model is satisfaction. For students to remain motivated during the instructional-learning process, educators must ensure that both the procedure and outcomes of instruction are satisfactory. By motivating

the second stimulus played a remedial role in problem-solving within this context. This can be illustrated in the following model (Fig. 1) that describes the principle of double stimulation:

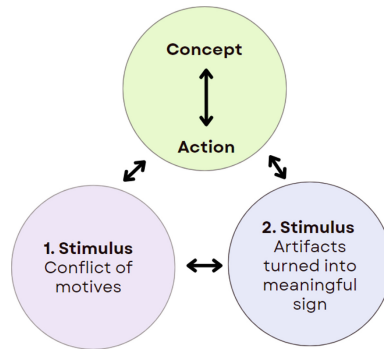


Fig. 1. The concept of double stimulation (adapted from Engeström & Sannino 2012, p. 204)

Here, the first stimulus is a conflict between different motives. The conflict is resolved by including a neutral artifact as a second stimulus, which is transformed into a mediating sign by giving the artifact a meaning (Fig. 1). This artifact can be something the individual assigns meaning to themselves, or it can be provided by others, e.g., an educator or a peer. This liberation from the original conflictual situation occurs in two steps: First, an artifact (e.g., booklet) is selected and given meaning, and second, you take a voluntary action using the mediating sign. A process occurs here where a problem situation is reshaped or recontextualized. The booklet in this study can be seen as a mediating artifact on several levels. Firstly, it provides PSEs with an understanding of the theoretical background to programming the greenhouse. If this is not enough to help them out of the problematic situation, they can use the images from the programming as a guide (see Fig. 4). At the last level, it is possible to download the entire algorithm for the programming to get out of the problematic situation. We use the booklet as a second stimulus to trigger the PSE's actions. Trigger refers to actions that can be verbal or take other forms, such as initiating an activity that facilitates the scaffolding of content exploration or engagement in problem-solving. Triggering is interpreted as pulling someone into a responsive activity or initiating a response (Pramling et al. 2019). As indicated here and further elaborated upon, triggering operates within a responsive framework. As a second stimulus, the booklet triggers by inherently necessitating a response; the response defines an action as a case of triggering.

2.3 ARCS Model of Motivation

As part of the task on the greenhouse, we use the ARCS framework to capitalize on the PSE's motivation and STEM self-efficacy. The ARCS motivation model, developed by Keller (1987), holds significant importance in enhancing the effectiveness of teaching methods and is regarded as the sole motivation model in education. This model emphasizes student-centered instruction, necessitating active communication between students

2 Conceptual Framework

2.1 STEM Self-Efficacy

Based on the principles of Social Cognitive Theory, self-efficacy has emerged as a significant concept within pre-service education, with notable implications for PSEs' decision-making processes concerning instructional activities, and their capacity to navigate challenging situations (Bandura 1977). First introduced by Bandura (1977), the concept of self-efficacy revolves around an individual's belief in their capability to perform a specific task successfully. This task can encompass a range of actions, such as a student lacking confidence in their ability to excel in a physics test, which stems from low self-efficacy. In alignment with Bandura's conceptualization of self-efficacy, this study defines STEM self-efficacy as an individual's belief in their ability to conduct STEM activities. Furthermore, we define the PSE actions concerning how they will enhance children's and adults' knowledge and comprehension of STEM subjects. We define this as PSEs' *STEM teaching self-efficacy*. It can be seen as a double-reflective perspective, where not only the PSEs' STEM self-efficacy is improved, but also their ability to reinforce others. Self-efficacy encompasses two key dimensions: personal efficacy, which pertains to PSEs' confidence in their ability to use STEM effectively, and outcome expectancy, which relates to the anticipated children and adults' outcomes resulting from their activities efforts.

Bandura (2006) further elucidated that an individual's self-efficacy beliefs originate from multiple sources. These sources of self-efficacy include mastery experiences, imagined experiences, verbal persuasions, and physical and emotional states. Mastery experiences, or performance accomplishments, are the primary foundation for developing positive self-efficacy beliefs (Bandura 2006). Moreover, self-efficacy theory emphasizes the role of vicarious learning, wherein individuals acquire knowledge by observing others' behaviors and the outcomes associated with those behaviors (Bandura 1977). It is widely acknowledged that individuals' self-efficacy beliefs can stimulate increased effort and a more substantial commitment to working with STEM (Bandura 2006; Menon et al. 2023). The theoretical framework of self-efficacy offers valuable insights into comprehending PSEs' belief systems and their perseverance in STEM disciplines. Consequently, we posit that higher levels of STEM self-efficacy will positively impact PSEs' willingness to engage in STEM activities in the future.

2.2 Double Stimulation Approach to Facilitate STEM Self-Efficacy

To promote the PSE's STEM self-efficacy, we used double stimulation to scaffold their learning. Double stimulation, initially conceptualized by Vygotsky in 1978, involved an innovative approach where he presented a child with a task that surpassed his current capabilities, constituting the first stimulus. Alongside this task, a neutral artifact was introduced as the second stimulus. Notably, Vygotsky frequently noted that the child would frequently incorporate this neutral artifact into the challenging situation, transforming it into a meaningful sign that aided task resolution. The first stimulus guides the activity and illuminates the problem space. Vygotsky (1978) defined the second stimulus as an artifact or sign that helps participants organize the activity. Introducing

Educational reforms that focus on improving pupils' competences within the areas of STEM are widespread today and have lately also been introduced in kindergartens (Campbell et al. 2022). The increasing emphasis on STEM from an early age has made it critical to provide PSEs with a solid foundation of knowledge and skills related to STEM. A limited amount of research has been conducted related to STEM in early childhood (Campbell et al. 2022), and very few studies have examined PSE's perceptions and confidence in implementing STEM education at an early age (MacDonald et al. 2021; Margot & Kettler 2019; Wan et al. 2021). However, several researchers have highlighted the importance of an early focus on STEM subjects (e.g., Clements et al., 2021; Gozum et al., 2022; Wan et al. 2021). Focusing on STEM early on can help foster children's natural curiosity through appropriate and playful experimentation and help support their later understanding of STEM subjects (MacDonald et al. 2020). According to Campbell et al. (2018), educators' attitudes toward STEM are relatively positive, but their confidence and self-esteem are quite low, which can hinder the introduction of STEM to children. To engage young children in high-quality STEM experiences, PSEs must provide them with opportunities, resources, and support to make it meaningful (Bagiati et al. 2015; Gozum et al. 2022; Li et al. 2021).

In response to the need to encourage more PSEs in STEM and build their self-efficacy beliefs, we have purposefully designed and planned instruction to engage and captivate PSEs' interest in STEM to promote motivation and long-lasting understanding. According to Jia et al. (2021), self-efficacy can be seen as a constituent of intrinsic motivation (Deci et al. 1981) and describes one's judgment or evaluation of their capability to successfully perform a specific task (Bandura 2006). To address the need for more young people to find interest in STEM subjects and foster their belief in their abilities, we have carefully developed a course to captivate and engage PSEs. In the course, PSEs work on programming a microcomputer to control a greenhouse where they can grow cress. To support PSE's learning, we have developed a booklet based on the principle of double stimulation. A double stimulation process is a way of getting out of a stuck situation and using signs or artifacts for assistance (Vygotsky 1978). In this case, the booklet should be seen as a second stimulation that the PSEs could use when they get stuck with a task.

The study assessed whether STEM instruction influences the participants' self-efficacy. The secondary goal is to investigate the interplay of various factors that significantly contribute to PSEs' experiences in STEM fields and how they can transfer them to their later work fields by answering the following question: How does implementing a double stimulation approach to teaching STEM impact pre-service social educators' interests in STEM, and their STEM self-efficacy?

After this introduction we will present an overview of the conceptual framework. This is followed by the methodology of the study, results and finally a concluding discussion.



STEM Self-efficacy for Pre-service Social Educators

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Abstract. This paper studies pre-service social educators' motivation in a science, technology, engineering, and mathematics (STEM) directed project, investigating how double stimulation can help them develop and improve STEM self-efficacy. The study provides preliminary insight into the signs of the pre-service social educator's self-efficacy concerning STEM when working on a small-scale course on STEM activities. With the many educational reforms focusing on improving STEM-competencies in society there is also a heightened focus on enhancing the competencies of pre-service social educators. These educators are expected to have a solid understanding of STEM subjects and skills. The paper aims to unfold pre-service social educators' work with STEM activities concerning their STEM self-efficacy. The study focuses on how to support pre-service social educators when engaging in STEM activities with the methods of double stimulation. In the study pre-service social educators build and program an automated greenhouse. The double stimulation method provides the pre-service social educators with the help of a booklet, which they can use if they get stuck on a task. The number of participants was 14 pre-service social educators. The data included pre-service social educators screen recording of how they programmed the greenhouse, pictures, reflections, and surveys. The data were analyzed using a thematic analysis. As a result of working on the STEM project, the pre-service social educators showed signs of improving their confidence in their STEM capabilities and thereby also signs of improved STEM self-efficacy.

Keywords: STEM self-efficacy · Double Stimulation · Pre-service Social Educators · ARCS

1 Introduction

This paper examines how pre-service social educators (PSE) develop their science, technology, engineering, and mathematics (STEM) self-efficacy during a three-week course. PSEs are students in Denmark who, after their exams, can work in kindergartens, schools, and with children and adults with disabilities. Self-efficacy can be defined as the degree of confidence in one's ability to accomplish a task. It encompasses a personal assessment of one's competence in performing a particular task or action and the confidence in possessing the requisite skills to execute that task or activity (Bandura 2006).

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7 Conclusion

Creating a course, in our case, 9C, and making the materials available is not sufficient to ensure its take-up, so there was demand from the facilitator target group for training in implementing 9C which led to the development of the M9C course. The pedagogical approach in 9C was chosen to empower potential refugee entrepreneurs as a contrast to their more usual role of supplicant. As part of the M9C training, as well as a general belief in the empowerment of learners, this pedagogy was carried over to the M9C course.

Feedback from relevant stakeholders led to the development of M9C, differentiation of the 9C materials and the discovery of complementary pedagogical approaches between the Transformative Learning Circles and Mastermind.

The good practices that were used in the development of the two courses included:

- The tightly scripted sessions to help less confident trainers but from which more confident trainers could deviate.
- The visual tool at the center of the 9C course, the BMC, not only helps refugees with low language skills but makes it easier to transfer the course from one language area to another.
- The system of optional certification according to context.
- The mirroring of the 9C approach in the M9C train the trainer course, including working on a business canvas as a learning outcome.
- The inclusion of local experts at least twice in the 9C course and reflected in the M9C course through the making of a local case study video.
- The low-tech digital tools used to present the materials to be accessible on a handheld device and easily transferable to other digital media.

The challenge of promoting effective networking remains. The Stepper approach seems promising but rigorously tested investigations of the “working out loud” method remain to be completed.

The pair of courses is highly relevant to the new wave of refugees now arriving in Europe and elsewhere from Ukraine. We have shown how to adapt them to local area needs through the M9C course, which makes them relevant globally. As an example, there are plans for applying the M9C package to the promotion of Fair-Trade businesses in Africa aiming to sell to Europe.

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the pace of activity changes from tentative exploration to concrete actions to start the business. A handoff to continued support is how the 9C course ends.

We were unable to avoid the need to create an account to follow either course due to our use of Google tools, however, many refugees already have a Google account in connection with their email so we judged that this would adversely affect the fewest potential participants.

One of the challenges of the 9C course for both participants and the facilitators is the nurturing of a relevant network of professionals as this largely happens between sessions rather than during the sessions. For the participants the main issue is one of language and stepping outside the familiar circle of friends and family. For the facilitators, this is a challenge because it happens out of sight, and they may feel less equipped to help participants if they themselves have lower levels of business knowledge.

A major challenge in both projects was the reduced funding from the amount requested. In both cases this affected the piloting of each course. This would not be a problem under the current 2021–27 Erasmus + program which operates under a lump sum model where applications can only be accepted as presented or rejected.

6.3 Implications for Theory and Practice

The M9C project was a combination of accessible pedagogy and technology. The TLC pedagogical approach recognizes and values the skills that participants come with. We note an element of convergent evolution with the existence of TLC, Mastermind and EduSCRUM.

Designing for handheld devices reflects what is happening in wider society where Smartphone ownership outstrips laptop ownership by a large margin. Thus, paying attention to what learning materials look like on a Smartphone and how learners could reasonably be expected to complete, and share assignments will have benefits that extend greatly beyond our initial narrow target group.

Place-based efforts are likely to benefit a much wider target group than the initial refugee group. Whilst we were targeting the needs of refugees and their facilitators, our small pilot shows that these types of initiatives would appeal to a wider range of locally based groups.

One major remaining challenge is how to make the networking between sessions even more effective. We encourage facilitators to suggest that participants with overlapping needs could arrange visits and meetings together. Feedback shows the video case studies and expert visits during the course tend to be very powerful. We could work further in the direction of Stepper's "Working Out Loud" approach (2020) to make networking less awkward and stressful, and more of a mutually beneficial exchange for both parties. This would then reflect the process during the sessions between the participants.

Course materials in Google Slides with implementation guidance in the speaker notes, and all other materials in Google Drive, are portable, low-cost, and transferable.

these was appreciated. Feedback was gained through a post-course survey issued shortly after the end of the course and during a follow-up social event in an interruption of the Covid 19 restrictions three months later. In particular, the local case studies of new refugee businesses carried the most weight. This could seem paradoxical in that they, by definition, knew less than the local bankers, suppliers, and small business advisors, however the peer effect was very strong.

The course materials were accessible from a Google website and participants preferred to complete their BMC in paper format for the duration of the course. As a tool for the future, they produced a digital version at the end. The final presentation to an external expert in the last meeting was the impetus to set the BMC in a more digital format at this stage.

The M9C course has not been piloted in full even though this was planned. The two projects overlapped and M9C was also affected by pandemic restrictions while another significant reason was that financing was once more reduced at approval stage so that strategic amendments had to be made to work within the reduced budget. Two different M9C sessions were trialed at local events in Lithuania and Italy where they were well received (steps 1 and 3 of 9). The Lithuanian Red Cross expressed a strong desire to adopt the whole M9C package after attending the public event.

6 Discussion

6.1 Integration into the Current Literature

The two projects stretched over five years from 2018 to 2023 with a core partnership. This timescale allowed the consortium to test ideas and notice what worked and what needed to be changed or enhanced in the areas of pedagogy, certification, supporting technology and content.

The Transformative Learning Circle approach functioned as intended with participants working on their own personal BMC project while exchanging experiences with their course colleagues and giving useful feedback and practical support where they could. Similar approaches are found in the organizational world such as the Mastermind method (Garmy 2019) which seeks to offer the same benefits of a group of like-minded people each working on personal growth projects that support each other through discussion. This meant that our approach had legitimacy as an accepted professional practice although in both 9C and M9C we prescribed the structure to a greater extent than is usual either in TLC or Mastermind. TLC was appropriate for the 9C participants in giving them agency and especially so for the M9C course both as a model for implementation in 9C and as a way of promoting an egalitarian learning community.

The EduSCRUM method of tracking progress that was implemented in the M9C course helps to overcome the multi-faceted nature of that course's outcomes that includes, completing a BMC, making a video and localizing the 9C course materials.

6.2 Limitations

Whilst the M9C course can be effective as a standalone experience, in the case of the 9C course, follow-up is needed. This could take the form of one-to-one mentoring as

edited versions of the 9C facilitator handbook and 9C materials as well as a completed BMC and a local case study video for use in the local version of the 9C course.

However these learning activities are shared with the facilitator, the issuance of a certificate of attendance and completion needs to be more secure and verifiable by external stakeholders. The project has tested a commercial option, Qryptal, and the use of certificated PDFs using Public Key Infrastructure (PKI) and a QR code that leads the reader to the certificate specification and confirms the identity of the issuer and recipient. The EU has recognized the need for such secure certification and has developed their own European Digital Credentials for Learning (EDCL) which can be used free of charge but require specific prior technical recognition to operate. In the M9C project we leave the final choice of certification up to the RSO as it is possible that they already have a preferred method. In this case our contribution is the certificate specifications. We describe implementation of Qryptal, certificated PDFs using PKI, and the EDCL in the technical guide we provide to RSOs.

5 Results

We piloted the original 9C course in Denmark and asked for feedback on both courses from potential refugee participants and RSO staff at public events in Italy, Greece, and Lithuania. The pilot was disallowed in the original Erasmus+ KA2 application for administrative reasons but the Danish partner was able to secure funding from the local municipality to run one very small scale iteration of the course in her area. The course was advertised locally in supermarkets, language schools and the local libraries and the Danish partner also got permission to recruit from three classes at the local language school for foreigners (including refugees).

In the pilot run of the original 9C course, we experienced that it was of wider interest than we had intended. Not only did we attract two refugees as contributors, but we also attracted two non-EU foreigners who had migrated to Denmark for other reasons, and a native Dane who had recently moved to the course location and felt she needed to grow her local network from almost zero. This indicates that the need to extend one's local business and professional network after moving to a new area is widespread for those intending to start a new business. The 9-week run of the course was disrupted by the Covid 19 pandemic, but the course continued online with the final presentation session taking place also online with the participation of a journalist and a local business advisor who gave feedback to our participants.

One concrete example of the benefits of forming a cohort around starting a business in a new area concerned logistics. One pilot participant was already importing a product into Denmark at great cost using air transport. This prompted another of the participants to mention that one of her relatives had previously worked for Maersk, the global shipping company, and that she could establish a link to explore maritime shipping as a cheaper alternative. It is exactly this sort of exchange that the 9C course was designed to promote. This example also shows the impossibility of expecting facilitators to be able to anticipate every question that 9C participants are likely to have.

While it could be argued that any individual could set up meetings with relevant professional contacts, the post-course feedback showed how greatly help with enabling

Site with links to all the presentations and some additional local information. As we moved into the M9C project we explored the possibilities with a wider range of Google tools.

The solution we adopted was to gather the course materials on to a Google Drive folder (see Fig. 3). Sadik (2017) found that this was a practical way of sharing course materials which students actively liked.

M9C-LowTech LMS

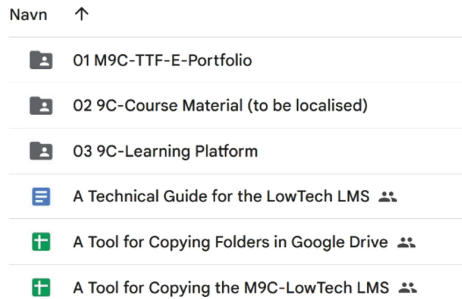


Fig. 3. M9C and 9C course materials template folders

The link to this shared folder is freely available on the M9C project website under the following menu item: Courses - > M9C Learning Platform - Google Drive. A new RSO wishing to implement the courses could copy the M9C Learning Platform (Google folders and files) by following the instructions in the following file: A Tool to make a copy of the M9C-Learning Platform for the RSO. The M9C Learning Platform contains A ReadMe file for Instructions that explains what kind of resources are available and instructions on how these should be used.

We facilitate prior inspection of the materials by mirroring the course materials on a WordPress website (Mastering 9 Conversations) using the Lifter LMS plugin. The materials are presented using the open source H5P book tool (H5P, n.d.) as a way of mirroring the slides and speaker notes of the original presentations. The materials can be viewed without creating an account. This also demonstrates that the materials can be transferred to other presentation modes.

Tracking and Certifying Progress

Tracking participant progress is necessary if certificates are to be issued. As argued earlier, the demand for evidence of attendance and completion is likely to vary according to context. When certification is necessary then tracking progress and certification are two tasks that can be carried out in different ways. Depending on the scale of implementation, progress tracking can occur on a very simple basis starting with pen and paper or a digital document filled in by the facilitator or trainer.

In the 9C course there are tasks that must be completed each week of the program to qualify for the final completion certificate. In the M9C course, there is a requirement to complete an e-portfolio that, in addition to learning diary entries, will contain the final

the presentations can be saved as PDFs that include the notes, and then distributed as workbooks.

Devices

We use the digital format as a convenient way of passing on the courses from one stakeholder to another. We also needed the assignments to be presented digitally in most cases. One important activity in the 9C course is to build up a contact list of professional people that can help with various aspects of the proposed business and this is best done digitally to take advantage of automatic links between emails and telephone numbers. In the M9C course, one of the important activities is to produce a case study video of a local refugee business.

A possible exception to the use of the materials in digital format is the completion of the BMC template where it is often more convenient to work with a paper version that can easily be amended using sticky notes. Editable digital versions of the BMC are available but perhaps not so convenient to interact with on a Smartphone and the paper version works best during face-to-face sessions when sharing ideas with course colleagues.

We also discovered the advantage of having the materials online while running the pilot 9C course as Covid-19 struck and we were able to continue online with minimal disruption.

Learning Management System

Both courses are designed to take place primarily face to face. The learning artefacts that participants produce in the 9C course center on an ongoing learning diary, a growing contact management list and an increasingly detailed BMC. In the M9C course the major learning artefacts include an ongoing e-portfolio, an increasingly detailed BMC, a localized version of the 9C materials and facilitator guide, and a local case study video. Both courses result in authentic outputs which the participants can make use of once the courses are over.

The restrictions on face-to-face meetings during the Covid 19 pandemic demonstrated that the materials were also suited to an online cohort model.

The technical requirements for the two courses are as follows:

- An editable repository for the nine slide presentations that make up each of the two courses.
- A link to the template for the e-portfolios that can be copied for each of the participants.
- Routines describing how you can track and verify progress on the certificate for each 9C participant.
- An editable repository for the support documents, 9C facilitator guide and M9C handbook and technical implementation guide.

Most RSOs do not have access to their own fully featured learning management system (LMS). It is possible to rent space on a commercial LMS, but we were wondering if it was possible to run the courses conveniently using freely available tools. We had already offered the 9C course as a series of presentations that could be used as PDF workbooks and during a pilot of the 9C course we had presented the course on a Google

The most critical outcomes of the M9C course are a thoroughly worked out BMC describing how the 9C course could be implemented in the participant's organization and a better knowledge of the local business landscape which includes the production of at least one case study video of a local refugee business that can be used as study material in their upcoming 9C course.

The materials that were produced for both courses contain little in the way of content and are rather discussion prompts within a timetable. These prompts could seem overly scripted. However, the aim is to give support to the less experienced facilitators, while more experienced facilitators can easily ignore and/or adapt the script if the main aim of each session is achieved.

4.2 Certification and E-portfolios

The assumed primary motivation of 9C participants is to develop their business idea with certification of this process not strongly desired. On the other hand, if refugees are in receipt of state welfare payments, they may need to account for how they spend their time, in which case certification may be necessary. To meet this possible demand, the M9C consortium developed certification for the 9C course and an e-portfolio approach for the M9C course and for the newly differentiated 9C course. If the RSOs do not have access to the mainstream, secure learning management installations that are common in education, this gives rise to some technical challenges which are explored below.

4.3 Technological Ecosystem

The 9C and M9C courses consist of timetabled discussion and activity prompts presented as a series of presentations with speaker notes. The M9C course mirrors the format of the 9C course as an effort to train future facilitators in the pedagogical philosophy of the 9C course. One of the key considerations of the M9C project was to make the materials as accessible as possible both to participants and to the facilitators and their organizations. We took into consideration that the refugee participants would most likely be using their Smartphones to access material and make notes (Betts 2017). In the 9C project we had tried out the phone app route but in M9C we decided that we should choose a more operating system agnostic route. We were also mindful of the low resource environment of most RSOs as well as the fact that running the M9C and 9C courses would likely be an occasional event that does not require the full panoply of secure learning management systems of a dedicated educational organization. The following factors were the most relevant.

Materials

Both the 9C and M9C courses are designed primarily as a place-based, face to face course. We prepared the materials as a series of Google Slide presentations, one for each of the nine weeks. In the presentations we made use of the speaker notes, initially as guidance for the facilitators, but it became apparent that in an egalitarian setting, this guidance was equally useful for all the participants. Although the format is a Google Slide presentation, this does not imply that the sessions must run with a projector, as

4 Methods

4.1 Learning Outcomes

To determine the learning outcomes of M9C we used the DACUM approach (Norton, 2004) to analyze the job of a 9C facilitator, starting with how to make the case to run a 9C course, implementing 9C and dealing with post program activities such as evaluation. This led us to propose three main learning outcomes.

1. To have sourced relevant information to produce a localized business model for offering the 9 Conversations training in their area and/or organization.
2. To be familiar with the materials of the 9C training (either to facilitate it themselves or to be able to support others in facilitating the program).
3. To know how to lead each 9C session using the suggested process (either to facilitate it themselves or to be able to support others in facilitating the program). This includes administration of certificates, suggested tools such as EU Skills Profile Tool for Third Country Nationals (EU, n.d.), and curation of materials.

Each of these main learning outcomes was further sub-divided for the purposes of the M9C course (Mastering 9 Conversations, n.d.).

The learning outcomes of the original 9C course were for participants to be able to:

1. Complete an EU skills profile that will be useful in presenting yourself to your new professional network.
2. Decide on a business idea to explore in the rest of the course that links the personal profile (in the EU skills profile) and the new local business environment of the participant.
3. Explain what a BMC comprises (for example to a fellow refugee).
4. Produce a BMC for a specific business idea rooted in the local community and personal context that includes all nine elements of the BMC.
5. Give constructive feedback on your study colleagues' completed BMCs and reflect on your own.

In theory, the nine weeks of both courses are meant to reflect the nine sectors of the BMC with the focus moving from one sector to another over each of the weeks. In practice, there is much to do in preparation before discussing the first sector. Many of the sectors interact and it makes sense to discuss them together and each course ends with the presentation of the group's ideas to an external expert. Therefore, in the end, four of the weeks are devoted to exploring the nine sectors, while the remainder of the time is dedicated to finding out more about each individual's skills, how to extend your network, the local area, how to tell a business story and the final pitch.

In the 9C course, as important as the nine sessions, is the time between the sessions when participants are expected to extend their local network by contacting relevant people and organizations. These could include potential customers, suppliers, financial institutions, and logistics organizations. Part of each 9C session is a debrief of the contacts made and how they can be followed up.

The most important outcomes of the 9C course are a thoroughly worked out BMC that can be presented confidently and competently by the participant, and an extended network that serves as a basis for plans to develop and implement the business idea.

of an individual” (Slettl [2019](#)). Both courses aim to extend the entrepreneurial mindset, in 9C to start your own business, and in M9C to plan how to offer 9C within their RSO. The EU’s EntreComp framework (Bacigalupo [2016](#)), a set of 15 entrepreneurial competences (see Fig. 2) in an 8-level progression model, was used as the basis for the course as a way of building the entrepreneurial mindset, with its three main areas of Ideas and Opportunities (reflexive e-portfolios), Resources (through self-assessment), and Into Action (covering experiential elements such as the building up of a professional contact network or the making of a case study video). The facilitator role is that of an enabler, directing the discussion, organizing the venue, any materials and tools needed as well as organizing any guests or visits that the group wishes to undertake as part of their business canvas development.

When a person is defined primarily as a refugee, they are often in a supplicant role having to be careful to keep to the rules to avoid losing that status and being repatriated. The pedagogical approach in 9C was therefore carefully formulated to ensure that course participants were empowered by the process to further their business plans.

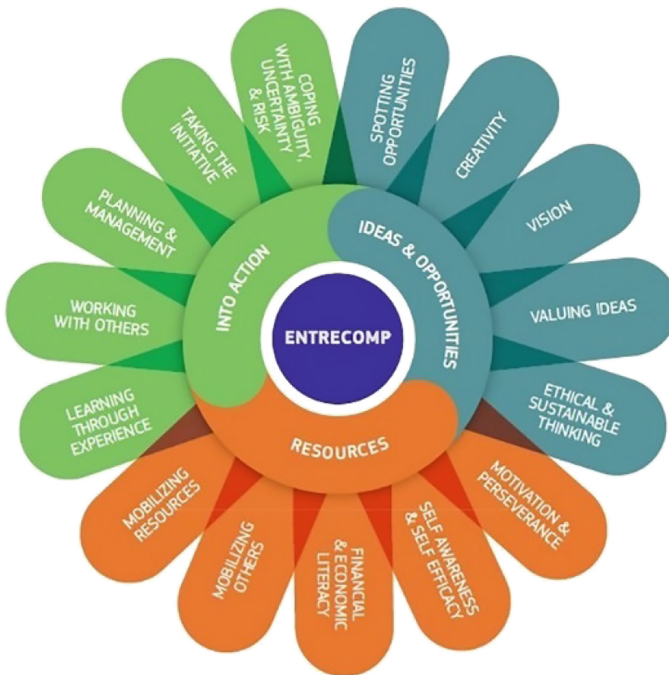


Fig. 2. The EU’s EntreComp framework of entrepreneurial competences

When developing the M9C train the facilitator course, the additional feature of documenting progress on the personal project through the EduSCRUM approach (Delhij [2015](#)), derived from the Agile method (Hazan & Dubinsky [2014](#)), was added. This enabled trainee facilitators to document their progress on their personal project which, in this case, was making the business plan for how to offer a 9C course.

3.3 Pedagogy

The original 9C course was based on a process of filling the one page nine-sector business description as developed by Osterwalder as the focus of a nine-week course (Osterwalder 2010). The BMC template (see Fig. 1) was used as the major vehicle for the development of a business idea for two main reasons. Firstly, that it is a visual representation of a complex idea, the interplay of different aspects of a business, and this would be easier to follow for participants with a low language level. The other main reason for using the BMC is that it is an established approach that is well-documented with many organizations creating entrepreneurship materials around its use. When it came to developing the train the facilitator course, we realized that preparing a business canvas about how to offer the 9C course was a value-added strategy. This would not only train the facilitators in the use of the BMC but also give them a useful product at the end of the process that they could implement immediately or expand into a full-blown business plan (for which we also developed a template).

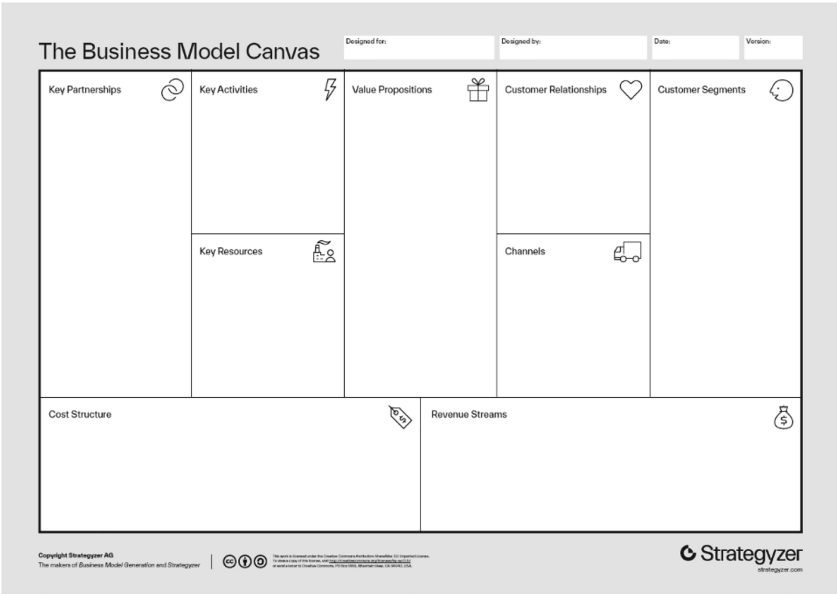


Fig. 1. The Osterwalder Business Model Canvas

The intent was to implement the Transformative Learning Circles (TLC) approach (Slettli 2019) in 9C whereby all participants are equal and develop their personal projects, in this case their business idea, through discussion. In TLCs “learning which promotes transformational entrepreneurial mindsets occurs in a dynamic iterative loop where individual level learning is combined with knowledge-sharing and interaction at the group level.” (Slettli 2019). The word entrepreneurial in this case is used to refer to its broadest definition as “a purposeful action and a capability of bringing about changes in the life

3.1 Target Groups

The two courses have different target groups. The target group of the 9C course was refugees interested in setting up a business as a way of supporting themselves and their families in their new country of residence. According to Betts (2017) 32% of his sample of Syrian refugees had previously owned their own business but only 1.5% of these had gone ahead and started one in their new country of residence, while 12% aspired to do so in their new circumstances. This represents a 10.5% proportion of the Syrian refugees as potential 9C course participants. These are most likely to be refugees with a certain level of security that they can stay in the new country for some years rather than asylum seekers for whom different laws and time horizons may apply. Another feature of the target group is that they have been resident for two or three years and are therefore able to take a course in the national language.

The target group of the later project, M9C, is the facilitators of the 9C course who may be uncertain about their ability to promote entrepreneurship but bring facilitator skills and a deep knowledge of their clients and the local area to the process. These are most likely to be volunteers or staff of refugee support organizations (RSOs).

3.2 Target Group Needs

Betts (2018) found that in another geographical context “when asked to whom they would turn for social protection in an emergency, nearly 90% of refugees in the city said they would turn to their own communities.” p.2. The refugees taking the 9C course therefore often have a supportive network with their compatriots but could benefit from closer contact with local people, especially those who could help them find out more about how business works in their area. According to Betts (2017) 97% own a Smartphone, whereas computer ownership is low and cannot be assumed. Therefore, we designed the 9C course to be completed on a handheld device.

There also tend to be language barriers between the refugees and the local population as well as a lack of understanding of key cultural differences which may affect the chosen business area. We attempted to design the 9C course to strengthen language capacity with a visual tool at its heart, supportive exchange of views as its main activity and facilitated meetings with local experts as a way of expanding perspectives.

The prospective facilitators could be volunteers or staff from RSOs. Both 9C and M9C were developed by a consortium including RSOs and university staff with expertise in entrepreneurship, pedagogy, and technical implementation of learning. Personnel from other RSOs may lack this deep knowledge and need to be scaffolded into being prepared to run these courses independently. The project consortium attempts to meet these needs by providing:

- Scripted materials for each course session
- Low tech and low-cost suggestions for implementation
- A participative pedagogy that values all participants’ contributions as well as recommending the inclusion of local experts at strategic points in each course

cultural differences that were relevant and any legal consequences could ultimately seriously jeopardize their permission to stay in their new host society. The project partners were aware, for example, of a local refugee who had imported a truck from Germany into Denmark without knowing that duty should be paid and began selling cooked chicken without any registration of the business as a food enterprise that needed to be inspected for health hygiene. We specifically developed the 9 Conversations (9C) course to address such legal issues, as well as the cultural adaptations necessary to ensure that their new business could generate sufficient income to sustain them. The 9C course was developed to enable the facilitation of the course purely by volunteers and Refugee Support Organizations (RSOs) staff, neither of which were necessarily business experts. It was therefore essential that an important part of the course should promote the process of expanding each participant's network so that they could get the specific help and support they would need in the medium term to thrive in their new country (de Lange 2021). Following on from the 9C course, it became clear that the prospective facilitators needed additional support and therefore the Mastering 9 Conversations (M9C) course was developed, in which mirroring the pedagogical approach taken by the original 9C course, was a deliberate training strategy.

Note that we use M9C to refer both to the project and to the train the facilitators course and that information about both projects can be found on the M9C website.

2 Context

While the European continent is no stranger to refugee influxes, the Syrian civil war posed challenges in terms of the size of the refugee flows aiming for Europe, which became significant from 2015 onwards.

The Erasmus + Mastering 9 Conversations (M9C) project targets refugees in European countries that wish to start or resume entrepreneurial activities in their new country of residence. The earlier 9 Conversations project developed a course to extend the refugees' professional network so that they could more easily start their business. The 9C course was based on Osterwalder's Business Model Canvas (BMC) and its nine sectors (Osterwalder 2010), hence the course title, 9 Conversations. The M9C project extended the scope of the initial 9C course by developing training for 9C facilitators in an additional course called Mastering 9 Conversations. The M9C project also enhanced the existing 9C course with videos to provide differentiation as we had found that potential 9C participants varied a great deal in terms of their prior experience and educational level.

3 Theoretical Foundation

There are many aspects of the M9C course which refer to the original 9C course and therefore it will be relevant to describe both. We refer to a train the facilitator course rather than the more usual train the trainer to emphasize the pedagogical philosophy. The aim of the M9C course is to enable prospective 9C facilitators to adapt the 9C materials to meet their own needs, to create a video case study of a local refugee business for use in their 9C course, to be able to carry out the facilitation process and to become more familiar with their own local business landscape.



Low-Cost Learning: Enabling Refugee NGOs to Lead Entrepreneurship Programs Independently

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Abstract. The challenge at the end of any project is how to embed its newly developed approaches over the long term as widely as possible. The Mastering 9 Conversations (M9C) project developed a train the trainer course to enable volunteers and refugee support organizations (RSO) to implement an earlier course that helps refugees to start their own business in their new country of residence. RSOs and their staff typically have no entrepreneurship training, therefore any training approach aimed at them must be easily implemented at low cost, while fostering a process that empowers all participants, including the facilitator. We describe how the combination of a pedagogical and low-cost tech approach of both our courses, run using Google Drive with secure certification, leads to increased inclusion.

Keywords: Refugee · entrepreneurship · transformative learning circle · Business Model Canvas · facilitation · place-based learning · Mastermind · EduSCRUM

1 Introduction

As Syrian refugees began to leave their homeland in large numbers from 2015 (UNHCR, n.d.), the European countries receiving them began to process and integrate those given leave to remain. Although Syrian refugees were not the first wave of significant refugee flows, they arrived in larger than average numbers and with a higher-than-average degree of entrepreneurial experience than was common at the time in the European Union (EU) (Betts 2017). Individual EU countries applied different conditions to the refugees: some required refugees to join the labor force as quickly as possible (Arendt 2022), while a small but significant minority of the refugees began to explore ways of starting or restarting their own businesses. Promoting entrepreneurship for refugees is useful (Embiricos 2020) but we should be wary of ascribing specific characteristics such as entrepreneurship, to individual groups such as Syrian refugees (Turner 2020). Many, however, sometimes started a business lacking an awareness of the legal requirements or

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the development of the extended teacher/mentor role(s). This appears to be critical as the teacher and/or mentor role, is potentially influenced by the introduction of AI and data-generated insights.

6 Conclusion

In conclusion, previous research shows that student well-being is a major concern in education, and that there is a concerning gap in data-driven research on K–12 students' well-being in particular. The present study also contributed with insights into how the use of a data-driven tool can provide benefits to students, through: 1) focusing on students' well-being, thereby providing an otherwise elusive metric, 2) offering insights at multiple levels – individual, class, and school – enabling targeted interventions, 3) encouraging data-informed actions such as the implementation of group-based activities, and 4) facilitating the development of caring pedagogies, thereby fostering a nurturing educational atmosphere. However, to fully exploit these transformative potentials, several challenges must be confronted. While this study contributes with teachers' experiences of using a data-driven tool for student well-being, the teachers highlight that the well-being tool influences a range of aspects in current practices for example, the need to agree on guidelines for operational use, data literacy, teachers' role, and responsibilities in relation to caring pedagogies, and educational improvement. All these dimensions are important for understanding the relationship between students' overall well-being and academic performance. In addition, we found that using any tool must be appropriately incentivised for both students and teachers, where competence, resources and leadership guidance is critical for effective outcomes.

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address issues related to student well-being, are not the same. Extending the findings of [40] we found that there are large variations in quality and time between schools. Almost all teachers expressed a lack of guidance in addressing aspects like emotional, social, and physical well-being. None of the teachers reported being professionally trained to guide and meet students in need to help them excel. These shortcomings may impact the experienced lack of resources (insufficient time, instruction, and guidance) and feelings of insecurity. However, with informed and guided leadership, exploration could be more systematic in the received values and visions.

As has been pointed out elsewhere, this includes highlighting what competencies teachers need to develop their pedagogical approaches and using these insights to support students' learning and well-being in meaningful ways [8, 29]. We did see example, in mentoring sessions and parent-teacher meetings, when a detailed focus or self-monitoring can support meta-cognition, which has been shown to improve cognitive outcomes [4]. With insights being used to inform teacher(s) (and parents) of a potential need for more social support. While the data-driven insights on well-being can inform planning and preparation in the pre-active phase, these insights were currently not intentionally directed toward learning activities, to support meta-cognitive abilities, evaluate intervention, or providing feedback when a student improves their well-being. This indicates that more guidance is needed on how to use the tool, but also, that schools can share their innovative adaptations of the tool, thereby fostering a supportive community for learning and growth.

The data-driven approach creates a number of unique values for various actors in school, enabling new effective methods that strengthen the school's ability to work preventively and improve their students' well-being in a continuous manner. A key value which emerged under the theme Teacher leadership (theme III) reflects opportunities of using the well-being tool to inform strategic and operational decision-making. Indeed, one challenge related to when teachers have the time to use the well-being tool and how the tool-use is used with students. We note a lack of theory to support integrating learning analytics tools. Theoretic grounding can provide teachers with a strategy for using data-driven insights to guide classroom instruction e.g., [38]. This can improve the school's ability to employ a scientific and evidence-based approach for building school improvement capacity and continuous data-driven school improvement. Building on [37, 40], the micro level encompasses the iterative process of data-generated insights and how these support each pedagogical phase. We see that teachers have access to data but need awareness of how to use it, reflect on the relevance of the data, and request new insights to support sensemaking to impact student behaviour or induce new meaning. On the macro level, on the other hand, addressing the workflow across multiple lessons or at the organisational level, the well-being tool was reported to provide support for abstracted insights. However, such opportunities also embed tension in what a teacher or a mentor is, in which teachers report on restrictions of resources and a need to empower teachers as leaders in decision-making and management. Indeed, the tensions also make visible that there are ongoing negotiations on what teacher and mentor roles may be, as identified by Faculty transformation (theme IV). This concerns if and to what extent schools are responsible for student well-being and how this would impact relational aspects and responsibilities, which in turn highlights the need to approach tensions in

students mark certain answers, then I must follow up! How will I get that time? How do I take those calls in a good, proper way? I became a teacher to teach. I didn't become a teacher to talk about well-being with teenagers. I don't feel super comfortable in it. I don't feel trained in it. I am very worried about it and handling that task well. (Teacher 6)

[We] have developed from a school where the teacher's role was defined as somewhat more authoritarian [...] to a school where the relational aspects like trust and respect matter more... (Teacher 1)

Modern faculty roles change as relational features are added to traditional instructional approaches. Some educators recognise the benefits of establishing trust and respect in the classroom, but others worry about their capacity to adapt and handle their new responsibilities. While teachers' approaches differ, none of the teachers interviewed reported being formally trained to handle psycho-social well-being. To ensure the best outcomes for students and educators in this quickly changing educational landscape, educational institutions must give proper training and support to teachers.

5 Discussion

In this paper, we explored upper secondary school teachers' experiences using a data-driven tool to support student well-being. Our research questions revolved around what benefits and challenges upper secondary school teachers experience when using data-driven tools to support student well-being, and how these factors impact successful implementation and integrating the tool into educational settings. We identified four themes: Insight diversity, Caring pedagogies, Teacher leadership and Faculty transformation, which we discuss using the theoretical lens suggested by [37], which includes orchestration aspects, phases of pedagogical practice, target actors, and levels of the iterative process. Our findings show that the well-being tool does present possible solutions that may support teacher by providing insights into student well-being, motivation, and other areas where support may be needed, which are imperative to identify the diverse needs of learners [1–3]. Drawing on the insights from the well-being data, we discovered a variety of perspectives, categorised as Insight Diversity under our first theme. This multi-faceted understanding broadens the utility of our tool, facilitating its application at various levels - from individuals, groups, or classrooms, up to broader program levels. This, in turn, could indicate areas of potential organisational improvement.

Exploring opportunities and challenges in Caring pedagogies (theme II), we noted that a key value is an incentive for the teacher collective to focus on the interpersonal values of high-quality relations and social support structure, where this well-being tool can capture data (which is otherwise illusive) to illustrate states, improvements, effects of interventions and identification of other critical factors, e.g., [29, 31]. Schools are generally advised to think about creating welcoming social learning environments that enable and support the well-being of their students [16, 17]. However, the challenges mentioned imply that many teachers might not feel prepared to address problems with students' well-being or to organise value-based and group-strengthening activities in response to the well-being tool. Knowing what interventions could work and having the capacity to

for that, it seems silly to ask lots of questions about how the students are doing, and then the students notice that there will be no difference. I say week in and week out, something like, “You’re lying bleeding like that”, and you say, “I’m bleeding, I’m bleeding”. Yes, we have received information, but there will be no plasters or bandages, either. So, what capacity does one have to receive it? (Teacher 1)

The teachers describe the importance of being responsive to the findings, for example in initiating *group-strengthening activities*. On the other hand, the teachers were not talking about value-based work or psycho-social support as something being generally agreed in between colleagues. Rather, it seemed to be up to each teacher to determine how to respond or not. An implication of such approach may be that if students notice that their data did not come to use, e.g., that the school was not using the data to making improvements, that the students may question the necessity of sharing how they feel.

4.3 Teacher Leadership

Recognising that teachers’ roles extend beyond classroom responsibilities and instruction is important. Teacher’s report being part of a decentralised leadership system in which they use the tool to save time, gain insight and ensure they provide effective student support.

As I teach English, I don’t take the students aside for mentor-related reasons. Then this tool gives me a good overview; that I can still see if there is someone marked on red, so I can reach that student. So, there is definitely a possibility that I will get insight into aspects that I would not have time to discover during an 80-minute, quite packed lesson”. (Teacher 4).

Above all, I think there is value in the fact that changes we want to make (possibly costing the school money) can be supported [by data]. Then it is good to have a tool showing them [the school leaders] that there is something to improve here. It’s not just that we [the teachers] have some insignificant opinion [...] then you are met by the school management: “Yes, and we are looking into it”, and then nothing happens. Now we can show the data. (Teacher 6)

Apart from using the tool operatively to ensure all of their mentor students are on track, teachers also point to using the data to underpin strategic decision-making, being able to present something to school leaders that may support an experience or a feeling of a situation with generated data that may reflect duration, intensity and spread of a problem.

4.4 Faculty Transformation

Faculty roles are changing as educational systems change. In the classroom, trust, respect, and well-being are now prioritised. However, teachers may object to having to take on responsibilities in relation to student well-being.

That was one of the reasons I wanted to use this tool - because it would be a way to save time. But by using it - I also accept taking on this role. If I identify that the

day,” feel stress, test anxiety or mood swings without these being investigated. Thus, the insights provided may be diverse in nature, reflecting both program level and individual perceptions and experiences. Underlying influencing factors may differ, which is why contextual awareness is key. Based on a contextual understanding, teachers may decide if it’s appropriate or not to address the issue with the student or student group. Teachers suggest this decision be made with colleagues, followed by a tactful, sensitive, and respectful approach. Whilst gaining new insights two of the teachers also shared their reflections on students’ attitudes towards using the tool.

Because now it’s more just like something they need to do, a necessity they have to go in and click on, and they do that quickly just to finish earlier, that is. (Teacher 5)

The students have, for example, mentioned that they don’t see it as that important because we haven’t spent much time on it. (Teacher 2)

Acquiring insights inevitably means that teachers and schools have the possibility to intervene if a group or an individual signals a decrease in the parameters measured or adjust and continue an ongoing intervention. However, how teachers frame using the tool, the time they dedicate, and how they then use it would influence student perception. If there is no framing or further use of the tool, students could approach it as rather pointless. However, teachers also reported that some students seemed to view it as a valuable opportunity to make their thinking about their well-being more concrete, which could help them to self-regulate and express their feelings.

4.2 Caring Pedagogies

The third theme, Caring pedagogies, reflects teachers’ views of supportive learning environments encouraging student well-being, educational participation, and success. The teachers, for instance, point out that the tool strengthens their capacity to identify students that need attention on an individual and group level, to improve aspects of social relations, and their capacity to address students’ performance dissatisfaction and sense of self-worth.

For my part, it’s like there are two perspectives: partly, it’s individual, finding individual students who are having a tough and difficult time, but it’s also very interesting on a group level, as well. Because the mentors have an extra responsibility for their own students, but in our work team, you are also part of the responsibility for the entire grade year, so to speak. According to the value-based work, we can work further on questions: “Is there a problem with the social relations between the students?” Well, maybe we need to add group-strengthening activities here for a while now, for example. And when students are dissatisfied with their performance, yes, but then maybe we should have a conversation about it. So, talk a little about education, grades, and value: “It’s not just your grades that make up your worth. You are more. - Like that.” (Teacher 3)

If you start asking questions about students’ well-being, you may also have to be prepared to act for students’ well-being. If you as an organisation are not ready

3.3.4 Levels of the Iterative Process

Fourth, the combined analytics framework employs perspectives at the micro- and macro levels. Building on [37, 40], propose that the micro level encompasses the iterative process of data-generated insights and how these support each pedagogical phase. Teachers *have access to data* but need *awareness* of how to use it, *reflect* on the relevance of the data, and request new insights to support *sensemaking* to impact student behaviour or induce new meaning. The macro level, on the other hand, addresses the workflow across multiple lessons, allowing tools to provide support for abstracted insights.

4 Results

We identified four themes related to teachers' use of the well-being tool: *I. Insight diversity* relates to context-dependent data and emphasises the need to understand contextual influences in order to interpret data relevantly, *II. Caring pedagogies*, which reflect experiences in relation to improving the learning environment, educational participation, and school success, *III. Teacher leadership* reflects teachers' use of the tool for operational and strategic purposes; and *IV. Faculty transformation* deals with reports on tensions in relation to the teacher role.

4.1 Insight Diversity

The teachers reported using the tool to acquire different kinds of insights that were otherwise unavailable to them. These insights allowed teachers (and students) to gain insight into individual students' motivation and well-being in a continuous way compared to traditional practices, and thus in a timely manner, identify who may need support, in addition to program-level insights.

To the individual parent-teacher meeting [we want the students to use the tool to] that they [the students] explore specific data and check historically: "How has it looked historically" and "What is the reason for that?", "How do you want it to be in the future?", "How will we achieve it?", "What should we do differently?" and so on. [...] So if there is something that we need to do to support the student, you have to pay attention to that. It's clear that if they have an exam the next day, then the workload might be perceived as high [due to that. So, you might have to think about checking [data] over time so that you do not point to something that applies to one day only.

[...]

(sitting with the application open)... now when I look at...(scrolling)...for example...I see here that it is quite clear that the girls here have much lower ratings on motivation, for example, which is perhaps a picture you have not seen elsewhere before. Of course, anyone can have a problem with motivation, but we often have the personal chats with the boys. (Teacher 3)

However, timeliness and being sensitive are key, teachers say; otherwise, students may stop revealing how they feel. Teachers underline that it must be ok to "have a bad

3.3 Theoretical Lens

Recognising the need to balance well-being and academic performance, we have chosen a multi-theoretical approach to analyse data, including consider stakeholders' varying purposes, roles and conditions for use and interaction, orchestration aspects [37], collaborative learning [38], exploring both the micro- and macro level perspectives. The framework combines four dimensions: *I. Orchestration aspects* relating to design and planning, regulation and management, adaptation, flexibility and intervention and awareness and assessment, *II. Phases of pre-active, interactive, and post-active pedagogical practices* that are supported, *III. Target actors, i.e., students, teachers, and researchers;* and *IV. Levels of the iterative process*, considering both micro- and macro levels. A description of the dimensions I-IV is provided below.

3.3.1 Orchestration Aspects

[37] included orchestration aspects proposed by [38]. They developed a framework for constructing learning analytics (LA) solutions that include four functional orchestration aspects: 1. Design and planning: preparing learning materials and methods. Applications that generate data-driven insights support the design of learning activities, 2. Regulation and administration: coordinating educational processes. LA tools provide essential operational data. 3. Adaptability and intervention: adjusting to unanticipated events or novel duties. Tools for learning analytics facilitate task adaptation, and 4. Awareness and evaluation: gaining insight into the learning processes of students. The range of tools includes visualisations and predictive approaches, and the fifth factor examines the roles of teachers, students, and other stakeholders in relation to the tools.

3.3.2 Phases of the Pedagogical Practice

Second, [37] included specific aspects from the Implementing Collaborative Learning in the Classroom (ICLC) framework by [38], which specifies five teacher competencies: planning, monitoring, supporting, consolidating, and reflecting. These competencies are mapped to the teaching practice's pre-, interactive, and post-active phases. Pre-active entails designing and preparing learning activities; planning is the primary skill. Typically, this occurs before the activity but can also be modified during the activity or redesigned afterwards. In interactive learning, the teacher facilitates the learning process and guides the students while monitoring, scaffolding, and consolidating. In the post-active phase, the teachers evaluate the outcomes and make modifications for future sessions.

3.3.3 Target Actors

Third it is also critical to consider stakeholders' varying purposes, roles and conditions for use and interaction. Here, we follow [37], and include students, teachers, mentors, and individuals in the community of research (where applicable).

3.2 Data Collection and Analysis

Data were collected at three upper secondary schools in Sweden during March and April 2023, following informed consent by the participants. Interviews ($n = 6$) with teachers (two female, four male) were conducted and recorded online using a videoconferencing application. A total of 204 min were subsequently transcribed verbatim. We adopt a reflexive approach to thematic analysis [33] and followed a six-step methodology suggested by [34]. The reflexive approach to thematic analysis, is rooted in qualitative inquiry [33, 35] and emphasises the importance of researcher subjectivity and the situated, interpretative nature of the analysis [33] rather than seeing interrater reliability as a marker of quality. This method was selected as it is suitable for well-being analysis [35] and interview data [36]. Each phase of data analysis was conducted by all authors in order to ensure transparency and rigour.

1. Initial familiarisation with the data: All four authors became acquainted with the general interview findings using a fully inductive approach (within the context of using the well-being tool). This entailed rereading the transcripts, making initial notes, and discussing the results as a group. During our meeting we both discussed initial themes and codes, thus our thematic analysis process was iterative, allowing us to revisit earlier stages as new insights emerged [35].
2. Developing initial codes: Following the generation of initial codes, the authors divided the interview transcripts and coded the data separately. This was accomplished by identifying meaningful data segments and labelling them. The codes were then distributed to the group, and the authors convened to discuss their individual coding and any emerging tentative themes. For example, with regards to “Insight diversity” the authors agreed that the data revealed gaining access to insights that the teachers had not previously had, not limited to well-being. Thus, instead of limiting the tentative theme to motivation and well-being insights, we agreed that there was diversity in the insights gained.
- 3-5 Themes: searching for themes, reviewing themes, and defining and designating themes: In meetings, while a high level of agreement among authors was observed for tentative themes, the focus was to adopt a reflexive approach to thematic analysis, rooted in qualitative inquiry [35]. This reflexive approach provided the freedom for each author to expand on their individual interpretations without being constrained by predefined codebooks or similar methodologies. As part of this process, the themes were reworked, and the data were categorised to capture the essence of the participants’ experiences. The tentative themes were discussed thoroughly to attain the same comprehension, and representative interview excerpts were selected. To maintain transparency throughout the analysis the authors continuously discussed their interpretations. This iterative strategy allowed for refining and elucidation of the themes, ensuring they were precisely defined and labelled.
6. Creation of the report: The final step involved incorporating the findings of the thematic analysis into a cohesive and consistent narrative. This included providing evidence from the data to support the identified themes and clearly explaining their significance within the context of the research question [34, 35].

that used AI and traditional statistical measures to distil data-generated insights on upper secondary students in Portugal found this approach to be more accurate than traditional methods [30]. However, the experiences of well-being applications and the data generated on student well-being may be considered an internal matter by schools, which may cause them to be reluctant to share their insights. In this regard, it would be difficult to determine the experiences and effects of interventions on teachers and students [11]. Nevertheless, it has been argued that continuous, systematic data analysis can lead to sustained school improvement [31]. [31] encourages school leaders and educators to create a culture of inquiry where data-based insights are utilised to identify areas of improvement, develop strategic plans, and evaluate the effectiveness of their actions. While research on wellbeing application in education overall is scarce, novel research, e.g., [9, 25, 30], on data-driven insights and well-being in higher education highlight how this is still developing, and the first K-12 initiatives are only just starting to be published.

3 Methods and Materials

3.1 Context and Participants

The software, EdAider Wellbeing, was developed in 2020 to assist schools with supporting insights to promote student well-being. The software tool was developed with school personnel, students, and researchers within a national research and development program (R&D) focused on data-driven school improvement organised by an independent research association: Ifous (Innovation, research and development in school and preschool). Now being used in around 20 schools in Sweden, it offers three features: facilitating high-frequency scientifically based screenings of a student's performance, providing students, teachers, health teams and school leaders with data insights that facilitate student reflection and learning about well-being as well as timely evidence-based interventions and data-driven feedback. During the R&D program, the authors established connections with schools. As three schools had used the tool the longest, we approached the principals and asked if they could suggest teachers, that used the tool from the start and who would have time for an in-depth interview. Adopting purposive sampling [32], we only approached teachers who were active users of the tool. Six teachers from this subset of schools were chosen for in-depth interviews, for this pilot-study, with a more comprehensive study under way. The teachers had varying years of experience: the one with the most experience had taught for 25 years, four teachers had 20, 16, 15 and 10 years of experience, and the one with least experience had taught for 4 years. All participants provided informed consent before data collection. In Swedish schools, a mentor is a teacher who supports, guides, and monitors a group of students' academic and social development. Swedish schools have mentee groups that are assigned to a mentor. Mentee groups are usually students from one class who share academic and developmental experiences. The mentor thus plays a dual role in the student's educational journey: They actively engage in strategies aimed at fostering emotional and psychological well-being, as well as assist the student's academic progression by providing feedback, engaging in dialog, and offering academic guidance.

e.g., [13–15]. The European Commission [16] emphasises the necessity of well-being at schools, highlighting the rise of mental health issues amongst school children and the additional challenges brought about by the Covid-19 pandemic. Internationally, countries like Australia, New Zealand, and Scotland have integrated well-being into their educational policies [12]. The OECD’s recent PISA results also indicate a decline of well-being as it is related to students’ sense of belonging, highlighting the timeliness of this research [17]. While there is no definite agreement on the boundaries of well-being in schools [18], researchers currently relate the concept to the school environment [19] and how positive influences on well-being may be account for calm, peaceful, and fun atmosphere [20], meaningful engagement [21], supportive relationships [20, 21], and negative influences by for example teacher stress [22], lack of social status, withdrawal and disengagement [23]. Thus, there may be some variations of what teachers mean when they talk about supporting student well-being in school. Still, an everyday understanding of well-being that aligns with the mentoring descriptions seems to relate to having an affective mode that does not hinder learning, engaging in learning in a meaningful way, and having functional relationships and a supportive environment. Whilst “well-being” is a commonly understood term in ordinary language, it is a broad and multifaceted concept, with cultural connotations and subjective properties, which does not easily lend itself to any general definition or measurement independent of context. Any attempt to generally define “well-being”, even in an educational context, uncovers a wide range of yet multifaceted sub concepts which would require further clarification for scientific scrutiny. For example, the European Commission defines well-being in terms of eleven aspects, ranging from feeling safe, valued, and respected, to social engagement, self-esteem, self-efficacy, autonomy, personal relationships, a sense of belonging, happiness, and life satisfaction [16].

2.2 Data-Driven Approaches to Support Student Well-Being

Existing research on data-driven insights (focusing on university-level students) have shown that internal factors (experiencing pain) and external factors (like duration of electronic device use) have been associated with student stress which in turn was associated with problems like burnout and depression [9] and poor sleep quality [10] and the effects of non-ergonomic study positions on student physical well-being (when students study from home) [24]. Other approaches analysed student emotion, as academic emotions provide insight into the student well-being for both on-site and online learners [25] and used wearable sensors to detect student academic emotion [26], Fitbit and smart-phones to detect loneliness [27]. In addition, we have seen initial contributions to theory and concept development to better understand student well-being as aspects related to worrying, health, and social factors when artificial intelligence (AI) is used to categorise and rate students’ state and behaviour, e.g., [28].

2.3 The Balance Between Well-Being and Academic Performance

There exists a delicate balance between fostering well-being and achieving academic excellence [12]. While insights into student well-being can inform interventions that support stress-management and academic re-engagement, as also noted by [29], a study

into the effectiveness of educational interventions and enable personalised support for learners [3]. However, to make sense of the data and apply it effectively, a strong theoretical background is required that can explain how different variables and factors affect learning outcomes [4]. One promising area of research that integrates data analytics and student well-being is using digital tools to support student well-being. Research has shown that student well-being is critical to academic achievement and inclusive societies [5]. By collecting data on students' emotions, behaviours, and attitudes, teachers and school leaders can gain insights into the factors contributing to student well-being and make informed decisions about supporting students' social and emotional needs [6]. Previous research has pointed out that it is particularly critical to consider how schools can ensure that the data is used in ethical and responsible ways that respect students' privacy [7] and develop their pedagogical approaches, using these insights, to support students' learning and well-being in meaningful ways c.f. [8]. Despite its significance, there is a noticeable scarcity of research on how data-driven methods can promote student well-being, particularly for K–12 students. Most of the existing research focuses on university-level students [9, 10]. Where, for example, [11] explored university student's adoption of technology in relation to their well-being, from the Technology Acceptance Model, and concluded that even though university students seem to display a growing acceptance of mobile applications, more research is needed, both that include other populations and build on empirical data. As theoretical insights are critical, but without empirical finding there is a risk that future theories will not reflect what is happening in situ [11]. To contribute to this gap, we explore the K-12 contexts. Researchers, e.g., [12] emphasize the crucial role teachers play for student well-being. This study extends that discussion by approaching the experiences of implementing and using a well-being application from the teacher's perspective, an aspect that, to our knowledge have not yet been explored in existing literature. Research questions posed in the study are:

1. What benefits do upper secondary school teachers report when utilising a data-driven tool aimed to support student well-being in schools?
2. What challenges do upper secondary school teachers report when utilising a data-driven tool aimed to support student well-being in schools, and how do these challenges impact the integration and successful implementation of such a tool in educational settings?

The primary objective of the study is to explore teacher perception of how a tool, used to provide data-driven insights is impacting them in their roles as teachers and mentors. Exploring these implications from a multi-theoretical approach we consider stakeholders' varying purposes, roles and conditions for use and interaction to offer insights that may inform an improved integration of similar tools, and improved educational strategies and interventions.

2 Background

2.1 The Importance of Well-Being in Education

As a way to address student well-being and assist students with developing and maintaining healthy habits, educational institutions have made student well-being a priority, developing formal strategies and frameworks for addressing student mental health



Tech for Student Well-Being: Exploring Data-Generated Insights in K-12 Education

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Abstract. Student well-being is important for inclusive societies and academic achievement. As studies have shown, well-being is associated with school success. Today, it's common for schools to use different technologies to collect and analyse digital data with the purpose of improving educational outcomes. Generally, this collected data focus on student engagement, attendance, and results, with novel advancements being aimed at supporting student well-being. In this pilot study, we analyse teachers' experiences to identify benefits and challenges during a spearhead integration of a data-driven tool for examining student well-being in upper secondary school. Using thematic analysis of teacher interview transcripts, we identified four themes: insight diversity, caring pedagogies, teacher leadership tools, and faculty transformation. The themes are discussed using the theoretical perspectives of orchestration, practice, process, and actors. Key results show that some high-value benefits teachers report on are gaining insights, saving time, and informing decision-making. The challenges include a lack of systematisation, guidance, and resources, and tensions related to defining the role and responsibilities of a teacher or mentor. We conclude that schools that work to support student well-being can benefit from the diversity of insights and practices related to the presented tool. However, an informed and systematic approach would be needed to leverage the benefit of spearhead integration. The contribution of the study is to provide insights on how a well-being tool can be used in an educational context to bring understanding of student well-being to teachers. Our results may inform decisions and guide integration and implementation practices in schools.

Keywords: Digital competence · Digital literacy · Student well-being · Innovation · Implementation · Integration

1 Introduction

1.1 Supporting Well-Being and Understanding Tool Implementation

In recent years, there has been increasing interest in developing adaptive learning environments that can accommodate the diverse needs of learners [1, 2]. The rationale is that collecting and analysing data on learning processes in real-time can provide insights

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